MOTORING

BY THE SAME AUTHOR

AVIATION: AN INTRODUCTION TO THE ELEMENTS OF FLIGHT

Reproduced from the "Auto"

HIGHWAYS OF OLDEN TIMES

The original Roman road over Blackstone Edge, near Rochdale.

MOTORING

AN INTRODUCTION TO THE CAR AND THE ART OF DRIVING IT

BY

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WITH FORTY-EIGHT PLATES AND MANY DIAGRAMS

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PREFACE

IN writing this book for motorists I enter a well-trodden field somewhat late in the day, for many authors have already catered for the needs of those who are interested to read the "popular technology" of the motor-car.

Nevertheless, the subject is broad enough to permit of some diversity of treatment, and in the present small volume I have endeavoured to provide an introduction to the mechanics of motoring in a form sufficiently original to justify its independent existence.

Particularly has it been my desire to have the book well illustrated, for a long editorial experience has taught me how much more effective are pictures than words to convey information of a technical character. In this the publishers, on whom rests the extra expense of the production, have generously concurred, and so from the unlimited storehouse represented by back numbers of the *Auto,* I have reproduced a collection of photographs and drawings that is, I believe, unique for a book of this description.

In their selection, as in the nature of the accompanying text, I have endeavoured to depict

general principles rather than to describe particular practice in detail. Many of the cars that form the subjects of photographs in this book are now changed in design, but others in turn have adopted the systems they illustrate, and so the principles of operation remain typical of those still employed in automobile engineering. Particularly do I desire that this should be recognized, both in justice to the firms concerned and to the book itself. The photographs have, in fact, been chosen solely for their merit as clear illustrations: where they are identified with specific makes of car it is mainly by way of courtesy to the firms concerned.

It is impossible that a book can long claim to be modern unless it is restricted to an explanation of basic principles, and in the main this is the purpose that I here seek to achieve. It is the proper purpose of the Press to keep the motorist informed of current developments, and whosoever would be *au fait* with motoring progress must necessarily rely upon some such source rather than upon a book, which, even under the most favourable circumstances, can only be revised occasionally.

A. E. B.

LONDON

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INTRODUCTION

THE MOTORIST OF YESTERDAY AND TO-DAY

TIME quickly changes many things beyond recognition, but the motorist certainly has undergone complete metamorphosis in the last decade. Instead of yesterday's grimy enthusiast energetically coaxing his "hot potato can" to renewed efforts of noisy labour, fashion now reclines at ease in cushioned luxury and silent speed.

Most of the outward glamours of the machine have gone, and of the early enthusiasm that made one revel in a roadside repair hardly any remains. Sometimes, when I experience the indescribable joy of finding myself at the wheel of a really living car, I recall some of those other days when I laboured so often and so long to induce even artificial respiration in an early "one-lunger," or tried so ineffectually to shield the lamps of an old tube-ignition Daimler from the stormy winds of the north-east coast.

It was, indeed, motoring of another sort then. When I think of the old pleasures of the road and compare them with the new road of pleasures, I cannot help feeling that, much as I enjoy the

present, when I can get it, those who know nothing of the motoring past from personal experience have missed participating in one of the most fascinating phases of social history.

He who commences motoring in the driver's seat of a modern car and enjoys from the first the refinements of a nicely balanced steering, an easy gear-change, unlimited engine power served by perfectly synchronized ignition and faultless carburation, can hardly be expected to realize how deeply these modern accomplishments can appeal to some of those who tried to keep their early cars out of the ditch by the aid of a wobbling tiller, to change speed with a handle that moved like the controller of an electric tram, and to shame an overheated, palpitating motor into some recognition of its obligations to its " maker's rating."

Friends of early motorists grew accustomed to receiving belated dinner guests about midnight, and, in general, any projected journey by car took on the hue of an adventure, of which none could foresee either the when, where, or how of its ending. Memory's tablets pass in review before my mind, and a mark on one of them recalls a journey up the Great North Road that ended in the small hours of a winter's Sabbath within the historic precincts of the city of York. With one tyre deflated by its fifth puncture and smouldering lamps that blinked their compliance with the

law through sooty glasses, the car dragged itself wearily through the deserted streets, while a couple of half-frozen occupants scanned the houses for the first signs of any sort of an hotel. Friendly advice from a belated stranger put us on the track of a neighbouring yard, the doors of which yielded at length to the strategy of climbing them in search of the bolt.

Having stabled the car by no other leave than our own, we essayed to gain entrance to the hotel by the vigorous use of the bell. In due course, a portly host appeared, ghost-like in the dim vestibule, and, scanning us through the glass, dismissed his would-be guests with no more ceremony than a wave of his arms. Remonstrance was futile, so we walked elsewhere on foot, leaving the car in its stable, well knowing that no stranger would be likely to take it *very* far away.

Finding another hotel, we rang again, and at length elicited virile response from a "boots," who had been sleeping in some distant attic. Being unable to see us afar off like mine other host, he had perforce to open the door, and in an instant we were safely inside. I can see again his frightened face, and not less distinctly can I recall my own, as it surprised me in the looking-glass of the bedroom. The poor boots would have liked to have turned us out, and no wonder, but he reserved his valour and merely contented himself

on this occasion with the discretion of relieving us of half a sovereign deposit; the which, I can still remember, was quite overlooked in the bill.

Yes, those were great days, and the joy of the open road was both exhausting and strenuous at times. Cars had no wind-screens then, and the dashboard served very effectually to deflect the maximum possible draught under one's overcoat. Many a time have I been stiff with cold on a long winter's drive, and the fearful rubber-neck poncho that came into fashion as a storm coat would so throttle one in its grip that after hours in the wind and wet it was a physical difficulty even to drink.

Having no wind-screens, drivers had of necessity to wear goggles if they cared for their eyesight, and many an old motorist to-day has cause to regret his neglect of this precaution. Without doubt, goggles are unpleasant things to wear, but it is essential to keep the dust and the wind from the eyes and nose if one is to avoid very unpleasant complications. A London specialist in these things has often told me of the large number of patients whose ailments coincided with this period of motoring and were directly attributable to its lack of protection.

Even when one was willing to use goggles it was not always easy to get a good pair. The glasses, if not perfectly ground, would soon promote

headache, and this as much as anything was responsible for the dislike in which most motorists held them.

The absence of protection on early cars also led to the necessity of travelling with an immense wardrobe. Hoods were as little in evidence as wind-screens, and whoever travelled by car had to keep wind and water out of his nether garments as best he could. There was nothing like leather or fur to keep out the wind, and nothing in any way equal to a good oilskin as a real protection against the rain.

The great difficulty in wet weather was to avoid evil consequences from sitting in the pool of water that would accumulate on the seat. There is, indeed, a very good story of a prominent motorist who arrived at an hotel one very wet day and ordered his trousers to be ironed while he took a hot bath instead of his lunch. Fabric waterproofs, as a rule, were useless, owing to the friction bringing the damp through in the places that it was most important to keep dry. On a motor-car, one would bump about on the cushion, one's back would rub on the upholstery, and one's elbow would scrape against the arm of the seat. From these three causes particularly, almost everything except an oilskin would fail in really bad weather.

Cars were noisier, and the engines had more vibration in those days: the chassis also was

shorter in length of wheel base and less well sprung. For these reasons there was more jolting, but some of the cars were quite fast on the road. Long journeys, however, were generally very tiring, even when they were concluded without roadside delays.

To-day, the motorist enjoys the most luxurious mode of travel that has been devised by man. He is comfortable, he is warm, and he is protected from the rain. Unquestionably, the wind-screen, the hood, and the high side-doors have worked wonders in this direction. Gone are the goggles, gone also is the need for heavy clothing. Even on an open car in winter, I seldom find it necessary to wear anything more than an ordinary overcoat, and in a closed car one can journey in all seasons without even this amount of additional clothing. I am still surprised, however, that owners of open cars do not more frequently fit screens to protect the occupants of the back seats, for a screen in front seldom accomplishes the purpose properly.

Cars have also grown longer, and no factor is of greater importance to the comfort of the occupants. It is, of course, easily possible to exaggerate the length of a car, but, in principle, a long wheel base improves the suspension. The engines and the transmission are now so much quieter as to have no apparent connection with the past, and a mechanical breakdown on the road

is almost regarded as a "novelty," so seldom does it occur with the modern car.

In short, from a weird contrivance that was the plaything of cranks, at which boys in the street threw stones and the public stared agape, the motor-car has evolved into the splendid horseless carriage of prophecy. It stands as the triumph of automobile engineering, and while in one form it has become the treasured possession of the rich, in another it has provided the public with such a service of omnibuses and taxi-cabs as was certainly never dreamed of in the philosophy of a former generation.

MOTORING

CHAPTER I

THE CHOICE AND UPKEEP OF A CAR

A MOTOR-CAR costs far too much money to be purchased without some consideration of detail requirements, for although the types of vehicle are limited, they are, nevertheless, sufficiently numerous to present a wide field of choice. Also, the possession of a motor-car carries with it contingent responsibilities that are common to other phases of life, but seem less apt to be recognized in advance in this connection. Thus, the prospective owner of a car whose personal interest is mainly centred on the pleasures of a motoring week-end, sometimes forgets the requirements of his wife and family, who will be able by the aid of the car so much to facilitate their own daily routine.

Again, in purchasing a car, many people do not seem thoroughly to appreciate the significance of the position that is now held by the motor vehicle in the economy of modern civilized life. Everyone in a certain position nowadays is ex-

pected to own a car, just as he is expected to live in a nicely furnished house, and it is important that his motor-car should be in keeping with the other possessions that from time to time he invites his friends to share. Too often, the prospective purchaser of a car who is well able to afford anything there is on the market, exaggerates the importance of low first cost, and in many ways distorts the relative values that should properly obtain in connection with the choice of a car.

Naturally, the point of view from which the prospective possession is regarded will colour after its own hue the relative values of the various attractions that cars can possess. Thus, if one's only idea is to have a machine that will go along somehow, it is not likely that more money would willingly be spent for the refinement of smooth motion. It is rather like being satisfied, however, with any sort of piano that will make a noise.

In the purchase of a car, as in the purchase of most other things, it generally pays to buy the best that one can afford. It is, without question, more desirable to travel in a large comfortable car that has a long wheel-base, and a powerful engine, for it is from such machines that one obtains the maximum of comfort and a minimum of fatigue on a long journey. It is by no means necessary, however, to travel fast merely because one owns a fast car. On the contrary, a well-designed powerful engine is ideal for travelling

slowly, for it is then that it works with effortless smoothness and in complete silence. A small engine, although it may develop a great deal of power for its size, is very apt to seem fussy even when doing quite an ordinary amount of work.

On the other hand, a small car may be equally as well made as a large car, and it will be less costly to buy, so that where price is a governing factor, a first-class make of small car should be chosen. Those who can afford to own several cars, will also naturally possess a small car, because it has many conveniences over the large car under certain circumstances. It is handier in traffic, can turn round with ease in narrow roads, and is altogether a more suitable machine for running about on odd journeys. Incidentally, of course, it is less expensive to maintain.

If it happens that the conditions of service for which a car is to be bought are entirely governed by such factors as have just been enumerated, then a moderately small car is preferable, even when the price itself is no object.

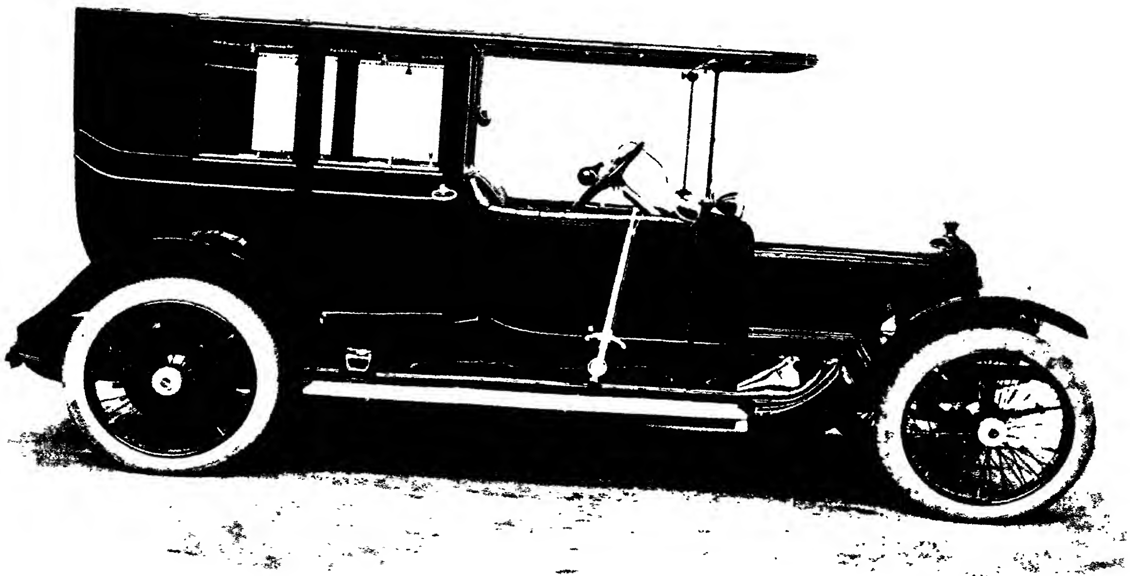
It is apparent, therefore, that the first point to be decided in choosing a car is the use that really is going to be made of it. For instance, a man or his wife may use the car six days out of seven in town, and on the Sunday they may not be interested in attempting any very long journeys. On the other hand, some people have comparatively little use for a car during the week, but look

forward to long-distance week-end touring. Others live more or less continuously in the country, and are not much affected by town conditions.

For each except the first class of user I would recommend a powerful car, so far as the purchase and upkeep of such a machine may be within his means. To anyone who habitually goes touring, and to whom long journeys are a pleasure, I would say without hesitation that the large car offers the most important advantages. For the man who uses his car mostly in town and who only goes just far enough into the country to enjoy the fresh air over the week-end, a large car is of less importance, for he will be able to do all he requires with a smaller engine, and in many ways he will find such a machine best fitted to his needs.

COACHWORK

The next most important point is to decide upon the general type of coachwork, and broadly whether the car is to be open or closed. In most cases, the lover of fresh air associates motoring with the open car, but when the man who has not previously possessed a car comes to review all the uses that may be made of it, among which by no means the least important to be considered is the convenience that the car will be to his wife when shopping or paying calls, it is more than likely that he will decide in favour of the landaulette.



A Daimler Landaulette, with extra side windows and extended roof

England has such an unsettled climate that it is impossible to be sure of deriving the full advantages that an open touring car should afford, and for this reason alone the closed car has rapidly assumed a measure of practical popularity that is out of all proportion to the small affection in which it is usually first held by the prospective motorist. Ladies especially find such a direct advantage in being able to go out to the theatre or elsewhere without making any special provision for the intermediate journey, that it is difficult to find an argument of equal weight in favour of any other type of carriage.

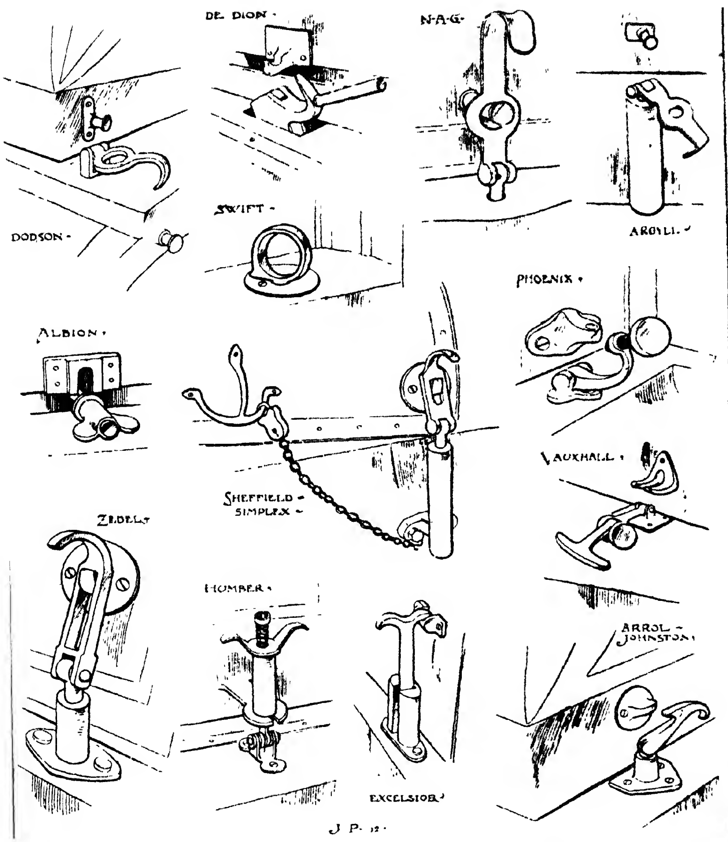
There are several types of closed car, and a selection is mainly a question of personal choice. By far the most popular is the landaulette, which is so constructed that the patent-leather hood at the back will fold down, thus to a limited extent making the rear portion an open car. There are also two types of landaulette, one of which is commonly known as a single landaulette, while the other is called the three-quarter landaulette. The important difference is the provision of an extra side window in addition to that immediately over the door. This is a distinct advantage in a landaulette, because it enables the passengers to have a better view of the road, and also it gives a better lighting to the interior. The single landaulette is often a very gloomy conveyance.

More perfect lighting is certainly obtained with

the limousine, which is a permanently enclosed car, having a rigidly constructed roof and sides. It is in less favour, however, because there is no part of it that can be folded down in fine weather. On the other hand, the airiness of such a car very largely depends upon the frequency with which the windows are opened, and its disfavour is frequently due to prejudice rather than to any fault in its design.

An extremely useful type of car for the man who drives himself and who appreciates the advantage of a closed car in all seasons, is the saloon car, so called from the fact that the interior, including the front seats, forms one compartment. Access is obtained to the seats through a central side door, which can readily be designed to give a very wide opening. The driving-seat is commonly a small arm-chair, and that alongside the driving-seat is arranged so that it can either be folded or pivoted to permit of the ingress and egress of the passenger. The back seats are similar to those in an ordinary car. The occupants of such a carriage are, of course, essentially *en famille,* and therefore it is not exactly suited to the requirements of those who need the services of a chauffeur.

As a type of car to drive I have always found the saloon car an attractive vehicle, if it is well designed in respect to the windows that open. Such a vehicle can readily be kept cool and airy, as well as free from draught. While it is a dis-



"Auto" Copyright Sketches.

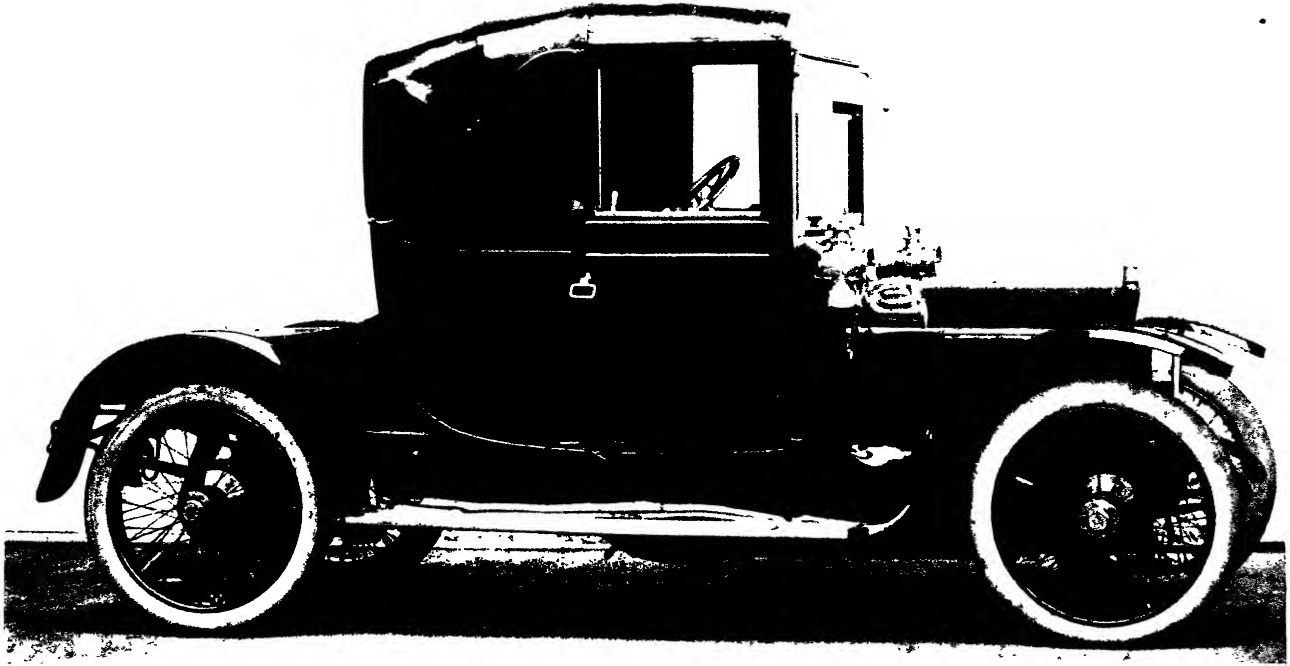
Methods of fastening the bonnets of cars.

advantage that the roof hides the sky, it is often a very distinct advantage that it should shield the driver from the glare of the sun, and when it comes to driving behind other cars on a dusty road, I would sooner be in this type of vehicle than in any other.

Drivers of saloon cars, and closed cars generally that are likely to have heavy roofs, should be cautious of the speed at which they go round corners, for several cars of this kind that I have used have shown some little tendency to roll outwards so much as to make steering difficult.

There have been many attempts to produce a convertible car, in the sense that it may be made either wholly open or wholly closed at will. The best solution of the problem that has yet been effected is the cabriolet, which has a leather roof suitably stiffened at intervals by transverse members that are supported upon the door-posts. When the roof is folded behind the back seat, like the hood of an ordinary landaulette, the upper parts of the door-posts can also be folded down across the back of the front seat and along the side of the body. The car is then completely open.

As may be judged from the description, it is essential that a cabriolet should be an example of the very finest workmanship if it is to be satisfactory, and the fact that it tends, in consequence, to be a somewhat costly type of car naturally militates against its general popularity.



A Wolseley Two-seated Coupé

HOODS AND WIND-SCREENS

Turning now to the open car pure and simple, it is, of course, essential that such a vehicle should be properly equipped with hood and wind-screens, so that the occupants may be suitably protected against bad weather. No one cares to travel unnecessarily far with the hood up, for there is an uncomfortable shut-in feeling when driving under a hood that is altogether out of proportion to the amount of protection from the rain that such a device affords. In consequence, it is highly desirable to have a hood that can be put up or down with a minimum of trouble and delay. To this end there have been designed hoods that are capable of operation single-handedly, and there is no doubt in my mind that such "one-man hoods," as they are called, are a great convenience.

The efficacy of a wind-screen depends on the distance that it is situated from the person it is intended to protect: if it is far off it is useless. In my own opinion, the wind-screen over the dashboard should be brought to within a couple of inches of the steering-wheel. It is absolutely essential to use the best quality glass for the wind-screen, in order to avoid straining the eyes, and it is important that the framework round the glass should be as narrow as possible so as not to obstruct the view. It is extraordinary how

readily a small obstruction of this kind can temporarily obliterate a comparatively large object in the mid-distance.

No matter where the front screen is situated, it is incapable of adequately protecting the occupants of the back seats from the wind, and owners of cars who desire to travel in the back seats themselves, or who wish to provide those who do so with every possible convenience, should certainly arrange to have their cars fitted with a separate screen for this purpose.

Regarding coachwork and upholstery generally, it is only necessary to remind the prospective purchaser that good coachwork speaks for itself. Moreover, it is not so much at the time of delivery as after it has been in use for a season or two, that first-class coachwork gives value for money by its freedom from rattle, draughty windows, and creaking joints.

COLOUR SCHEMES

Since the enclosed car has become so universally popular, the internal decoration has assumed a much-increased importance, and anyone who is selecting materials for the upholstery should bear in mind that the colouring thereof will form an ever-present foreground to the distance provided by nature. The fundamental tones of the countryside are green and brown, and as the natural shades that are thus provided are so much superior

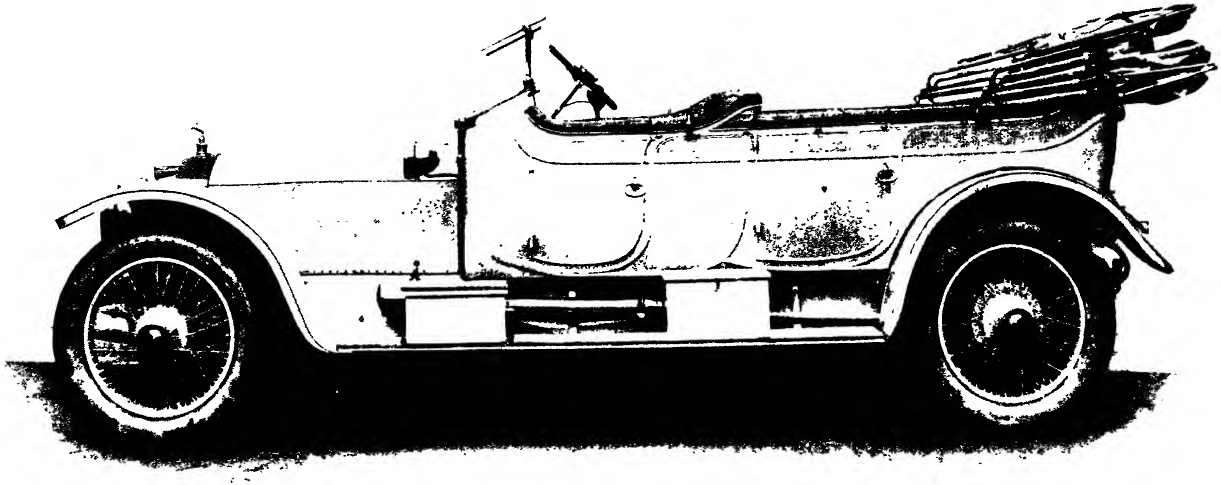
to anything that can be artificially produced, it is on the whole preferable to select a contrast to them as the basis of the interior colour scheme of an enclosed car.

The interior itself, however, should not be subject to contrast, although changes of shade are desirable. Especially should the ceiling be lighter than the floor, which latter also may, with advantage, be made darker than the walls. Red is pre-eminently a cheerful colour, and it has warmth. Pinks, ranging from salmon to rose, form an artistic contrast to the surroundings, but blue pinks must always be avoided. Blue in itself is soothing when well chosen, but otherwise is apt to be cold. A pale turquoise is as artistic as any, but not easily obtained in the right shade.

It is a mistake to suppose that light colours are necessarily less durable than dark colours. For one thing they show the dust less, and for another they tend to improve with age if the material is of the very finest quality, as it invariably should be. The extension of the principle of encouraging individual choice based on detail prices would do much to foster an increased range of colourings that are out of the ordinary but nevertheless artistic when properly chosen. There is no reason in the world why the interior of a car should be gloomy any more than there is any need nowadays to use the black horsehair furniture of the Victorian era. Indefinite tones, such as the fawn and

biscuit coloured cloths, are considered to be in good taste because they are quiet, but they have become undeniably ordinary, and it needs some little stimulus to ensure a departure in the right direction. The greyish green tinted cloth that is so popular for much the same reason has little else to recommend it, for there are few ladies, at any rate, who would hesitate to describe it as " difficult " if they once came to study the matter from the point of view of their own personal environment. The modern enclosed car is something of a drawing-room, and it should complete rather than destroy the effect of a thoughtful toilette. Much time and considerable money may also be spent on the perfection of minor detail as, for instance, in the selection of silver or ivory against a background of royal blue, of copper as an appropriate ornament on cream or light fawn, of amber against turquoise, and of jade in a setting of old rose. The use of special woods, too, is a most fascinating study ; mahogany, for example, not only possesses a beautiful grain in itself, but very often supplies just the note of warmth that is required to complete a decorative effect.

Of the outside of the car it is necessary to remember that it must harmonize with the background of nature, otherwise it will attract an undesirable attention that it is the object of good taste to avoid. Dark shades are thus for the most



A ROLLS ROYCE OPEN TOURING CAR WITH HOOD AND WIND-SCREEN

part desirable, and a really good dark green is one of the best, particularly as it permits a very wide range of interior colourings. It is also, by the way, one of the less expensive paints. A point to be borne in mind about the use of very dark colours, such as are almost black in tone, is that their smartness depends absolutely on their perfection of surface; the least blemish reflects a spot of light that draws attention to a fault that might pass unnoticed on a car that was, for instance, painted white.

DETAIL EQUIPMENT

While the colour of the upholstery is important, a more vital matter is comfort, and in order to obtain comfortable seats it is essential that they should have deep cushions. This is also an item for which the purchaser must be prepared to pay a proper price, but for those to whom comfort is a consideration and for whom long journeys are ordinarily fatiguing, there is no doubt that the really deep and well-sprung seat-cushion affords a large measure of relief.

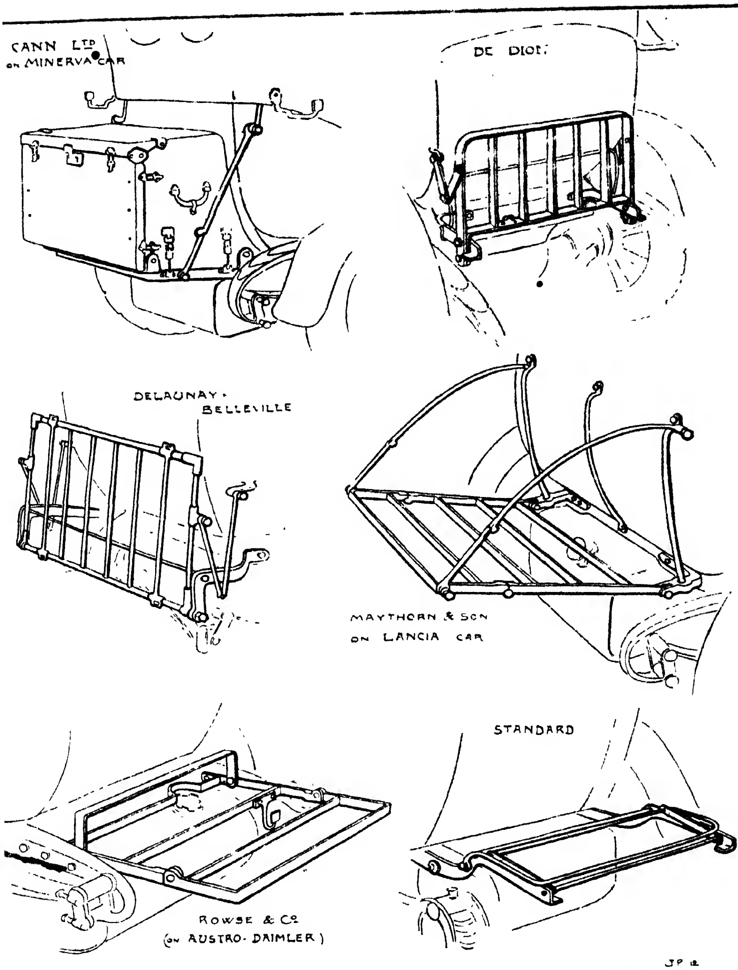
The motorist who buys an English car is faced with the necessity of specifying its final equipment. He must not only consider the more important matters that have already been alluded to, but he must take a personal interest in the various accessories that go to make the machine complete and ready for the road. Whilst on the

subject of coachwork, there is a minor point in connection with closed cars that is worthy of mention, and that is the utility of a small skylight in the roof. It is possible to make such a skylight watertight, and also so to design it that it can be readily raised. In a limousine, it is especially useful, and indeed in any closed car it has its advantages, particularly as a means of clearing the atmosphere of tobacco smoke.

In an open car, it is a convenience to have a rug rail on the panel behind the front seat, and it is also an advantage to have this panel itself upholstered with carpet or the like so that luggage may be carried without scratching the paint. In most cases, it is also convenient to have a foot-rest.

TYRES

No subject of car equipment is of greater importance than the tyres, but the tyre size is as a rule determined in advance by the chassis manufacturer. The main point of importance concerning tyres is that they should be large enough to carry the weight and to withstand the speed without undue strain. It is particularly necessary to bear this matter in mind if the purchaser happens to be considering an unusually cheap car at an inclusive price. Mechanical breakdown having been virtually eliminated from the troubles to which the motorist is now liable, it remains only to guard against delay caused by punctures. To this end,



"*Auto*" *Copyright Sketches.*

Grids for carrying luggage behind a car.

the car should certainly be equipped with a detachable wheel or a detachable rim, which, being carried on the car with a fully inflated tyre, is ready for use at a moment's notice.

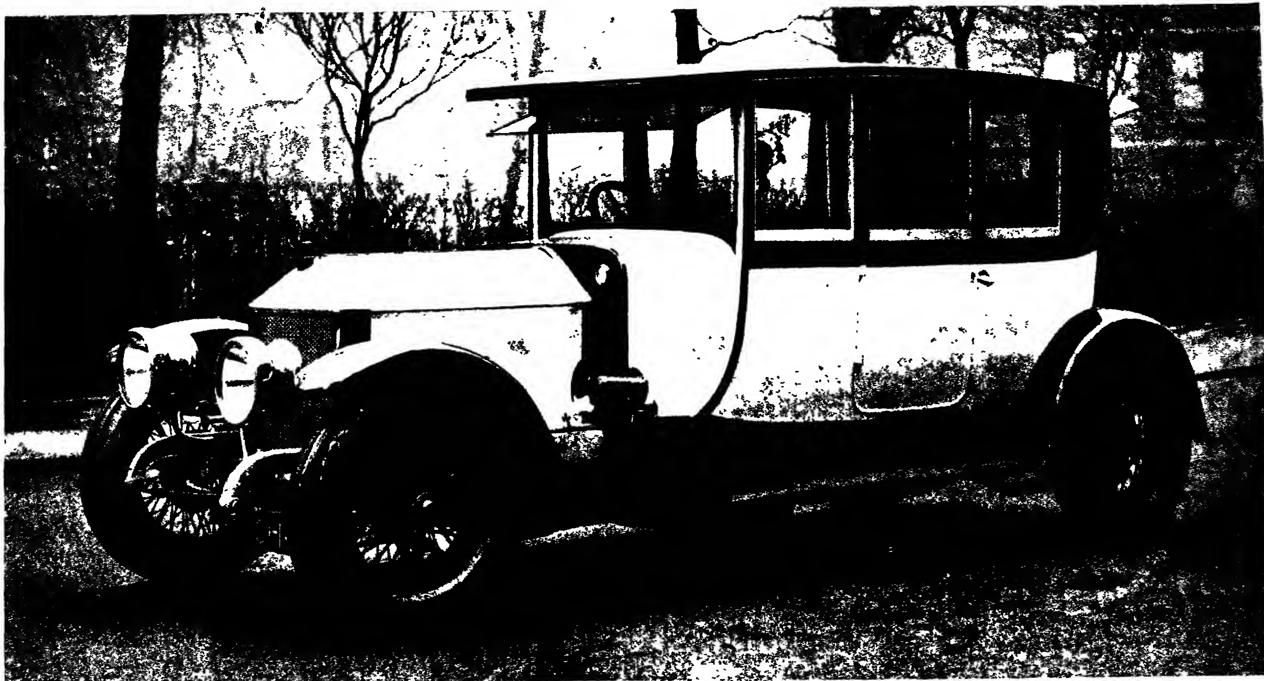
LAMPS

Next to the tyres, the question of lamps is an all-important one, for without good lamps it is neither safe nor comfortable to drive at night.

Headlights to be of any service whatever must be extremely powerful, and so designed as to throw the beam a great distance. A long-distance beam of light is not in itself visible to the driver, who continues to drive in darkness until it throws some distant object into relief. For this reason most drivers like to have some diffused light on the roadway and on the hedges near at hand. These qualities are merely a question of suitable lamp design.

Nowadays there are many very neat, very clean, and very reliable acetylene generators. Most people who have had experience of acetylene light are agreed, however, that for convenience, cleanliness, and reliability there is nothing to touch the dissolved acetylene plant.

Electric light on cars is steadily increasing in popularity, but there is still some difference of opinion as to whether electric headlights are adequate for serious night work. This is, however, surely only a question of the equipment, of using



A Metallurgique Saloon Car

sufficiently strong lights, and of having an adequate dynamo charging plant to maintain them at the proper voltage.

Whatever may be the opinion on electric headlights, there can be no question about the convenience of electric side and tail lights. Particularly will the motorist who drives his own car find the greatest possible advantage in electric light. It enables him to switch on when lighting-up time comes without the least inconvenience, and everyone knows how annoying it is to have to stop towards the latter end of a journey in order to comply with this detail of the law, when, being already in well-lighted streets, the light of the lamps themselves is not needed by the driver.

A point in lamp equipment that is at present undeveloped is the use of swivelling headlights. These are so connected to the steering-wheel as to be caused to look in the direction in which the car is about to proceed. There are few more awkward sensations than that of negotiating a dark corner with the headlights staring stolidly at some adjacent boundary instead of illuminating the road along which one is alone able to travel.

Speaking of special points in headlight design, it is important to mention the qualities of gold-backed mirror reflectors. The rays of light thus projected may be less intense when judged by the ordinary standard of candle power—that is to say, by their ability to cast a deep shadow—but their

powers of definition are remarkable. It is a light that has the quality of giving roadside objects better resemblance to their natural appearance than they usually possess in the rays of an intensely white light. This reference to yellow rays is also a reminder of the special goggles of this tint that it is possible to purchase nowadays. Those who are inconvenienced by the glare of sunlight should wear these chlorophile glasses, for they are a great relief to the eyes, and they have the advantage over ordinary coloured glass in that they do not seem to be darkened after they have been worn for a minute or two.

HORNS

Horns are a matter of choice, for any sort of sound instrument complies with the law. The advantage of a bulb horn is that it offers a greater range of control, and so enables the driver to modulate its voice to the equivalent of such expressions as "Excuse me," "Thank you," and "Get out."

The latter way of saying things is far more effectively accomplished by one of those noise boxes that are operated either mechanically or electrically. There are instruments on the market that might well be guaranteed to make everyone within half a mile scatter like hares at the first note. It is a great advantage to have such a fitting on the car, but its abuse is terrible.

Some of the electric horns are pleasant-toned and carry far. Very few people fit the button of an electric horn in the most convenient place. It strikes me as being especially inconvenient when it is situated on the steering-wheel, and even more particularly so when it is intended to be operated by the left hand. I hold the view that the left hand should never on any occasion be required to do anything but grasp the steering-wheel.

The button of an electric horn might very well be placed on the handle of the side-brake, particularly as the driver has ordinarily no means of blowing the horn when he is using the side-brake unless it is thus equipped. I once rigged up an arrangement of this sort to try the idea, and it worked splendidly. Incidentally it might draw manufacturers' attention to the desirability of arranging side-brake levers in more convenient positions.

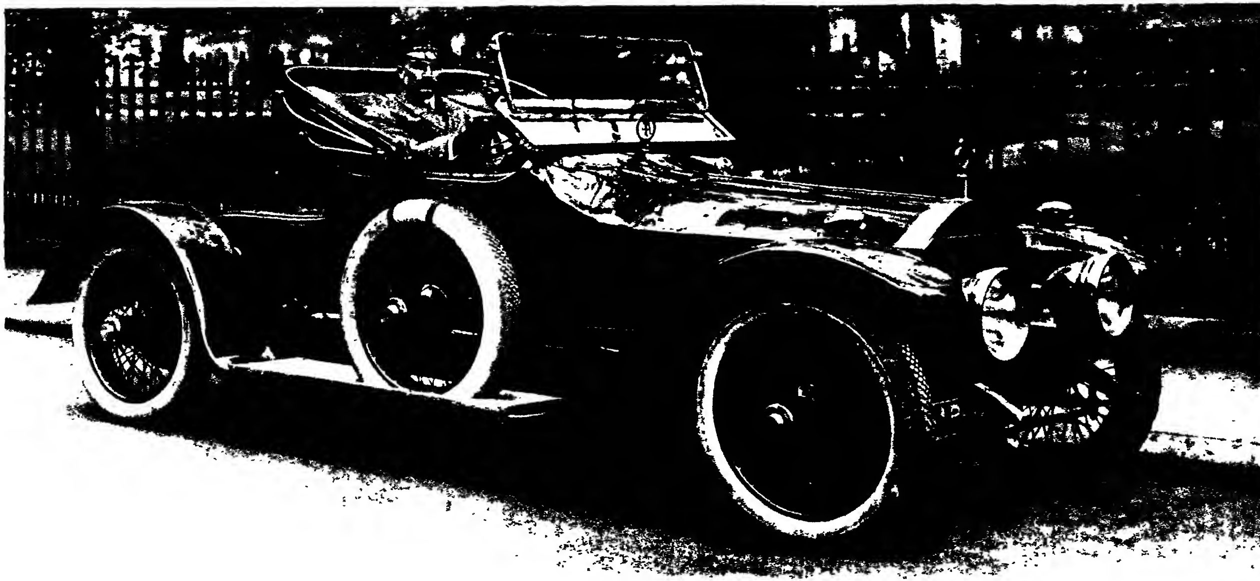
Another very convenient place is on the top of the door at the right of the driver's seat. Because the button of an electric horn is ordinarily very small, it might be a good idea to mount the entire beading along the top of the door on light springs, and arrange the switch beneath it so that the horn might be operated by pressure anywhere along the rail. It could also be operated by the elbow if both hands were needed for steering.

SELF-STARTERS

Of late, the tendency has, very naturally, been to elaborate the equipment of the car, and the latest convenience is the "self-starter." The device is for the purpose of starting the engine by pressing a button instead of winding the crank. Some of the systems operate electrically, that is to say some form of electric motor is arranged to turn the crank-shaft, the motor itself being energized by a battery of accumulators that are themselves kept charged by a dynamo that is driven by the engine. Another system that is in use admits compressed air direct to the cylinders during their "firing" strokes and so sets the engine in motion. The compressed air is stored in a steel reservoir that is charged by an air pump driven by the engine.

There are also other methods, but those just mentioned are the more important, and in one form or another are to be found on many of the latest cars. It is unquestionable that a self-starter is a great convenience on a big engine, which may require considerable physical strength to "swing" by the crank alone. On small cars, its value is very largely a matter of opinion. Of course, it is always a convenience to be able to start any car from the seat, especially in wet weather.

Some people do not readily acquire the knack of



Mr. S. F. Edge in his Two-seated Napier

cranking an engine, and to such the manual labour of starting-up is irksome. With a properly adjusted carburettor and magneto, any small engine should start on a single pull-up of the crank, and when the conditions are such that it will not start by hand, neither will it do so with the self-starter. Sometimes purchasers are apt to forget that it is just as essential to switch-on, to adjust the throttle and to set the ignition-levers in their right places when there is a self-starter as it is when the engine has to be cranked by hand.

COST

The preceding remarks have been directed in general towards the equipment of any sort of car irrespective of size or power, and it now remains briefly to discuss the classification of cars and to consider their cost and expense of upkeep.

There is no precise classification of cars that is suited to serve the purpose of a guide to the prospective purchaser, for any system of classification that is sufficiently comprehensive to be exact would also be too complicated to meet the requirements of the non-technical man. Some years ago the Royal Automobile Club sanctioned the rating of cars in proportion to the bore of their cylinders, and a formula was devised for expressing these sizes in terms of horse-power. This formula was solely for catalogue purposes, and does not necessarily express the power of the

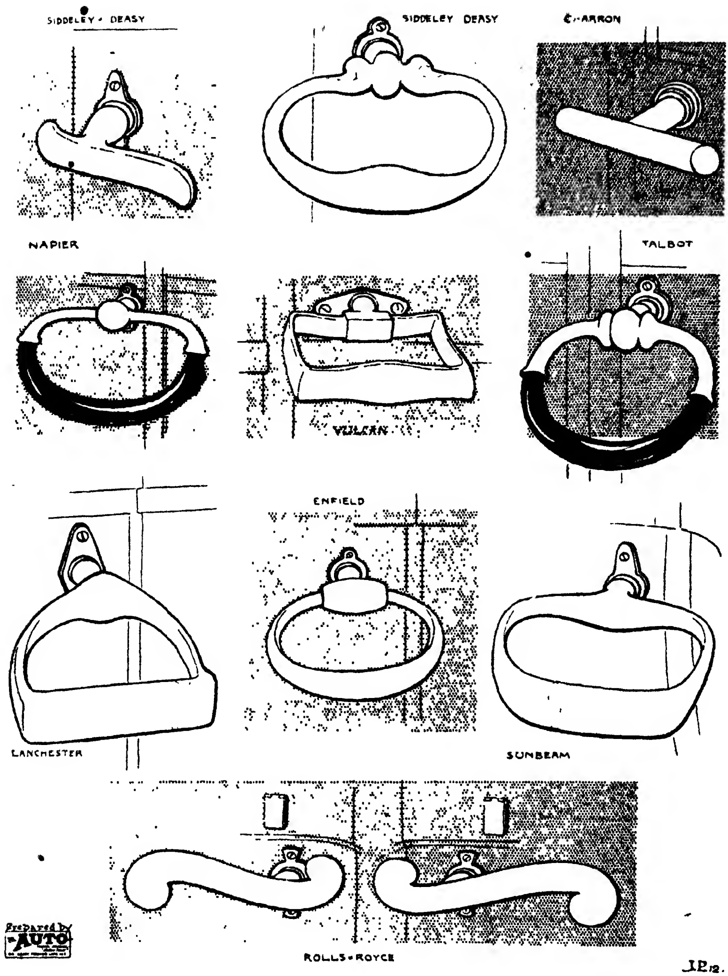
engine accurately; indeed, it is usually very much below the power that is available from modern engines.

Many factors that cannot even be expressed in the usual dimensions affect the capabilities of the engine, and the purchaser is wise, therefore, to consider the car's reputation rather than its mere size.

Broadly speaking, however, it is convenient to divide the most popular engine sizes into three groups, having respectively cylinder bores of 80, 90, and 100 mm. These sizes are intended to be elastic, but even so do not comprise the entire range of classes into which cars might usefully be divided. They do, however, cover the most generally used sizes at the present day. Each group of engine sizes is available in either a 4-cylinder or 6-cylinder engine.

Many cars are built that have engines much smaller than 80 mm., but for the most part these are used for 2-seated runabout cars. Similarly, cars are also built with engines frequently exceeding 100 mm., but such large engines are naturally intended for the very large and luxurious cars that a minority alone can afford to buy. Smaller engines now give as much power as large engines of earlier date, and the 6-cylinder engine provides a very powerful motor without using very large cylinder dimensions.

In choosing a car, it is necessary to bear in mind



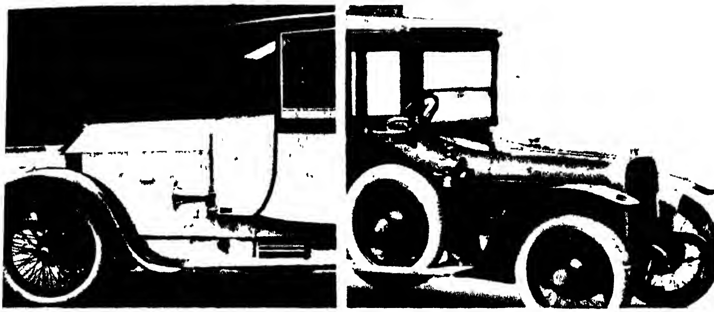
"*Auto*" *Copyright Sketches.*

Designs of door handles, with particular reference to those likely to be artistic on closed cars.

the nature of the coachwork required in order to be sure that the wheel-base will give sufficient accommodation and a conveniently wide doorway. Also, if the coachwork and the accommodation required represent a very heavy load, and at the same time it is desired to drive long distances at fairly high speed and to climb hills without delay, then a powerful car is essential.

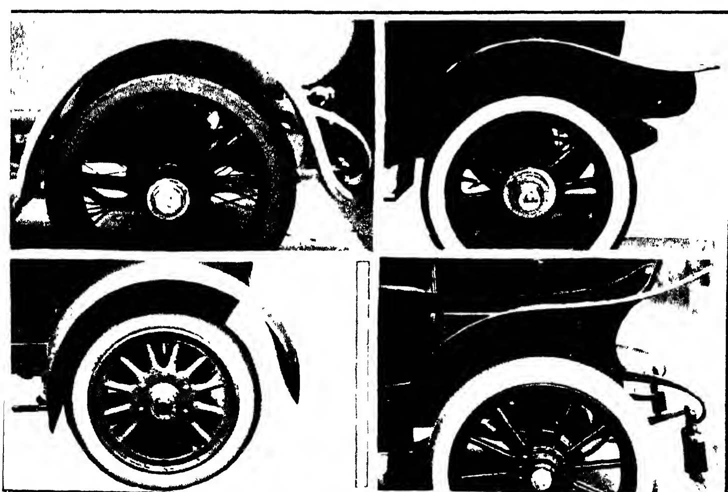
For any one class of car, considered in all its bearings, the cost does not vary much with different makers, but considered from one point of view only the range is so wide as to be confusing. Thus, it is possible to buy a 15-h.p. chassis for any sum from about £300 to £450. A mean value for a first-class make is, say, £380.

Although the price charged by one firm may be somewhat more than by another providing apparently the same object, the main difference that accounts for the above-mentioned range can readily be seen. Thus, one firm may provide a long wheel-base to accommodate closed coachwork, and will fit tyres to suit, while others will use the same-sized engine on a short wheel-base that has smaller tyres on its wheels. Again, on some cars there are four speeds and on others three speeds. There are also differences in lubrication, and many other refinements that contribute to the smooth working and longevity of the car, and have assisted in building up the firm's repu-



SCUTTLE DASHBOARDS

On the left is shown a Van den Plas body on a Metallurgique, and on the right an Argyll body in an Argyll chassis.



MUD-GUARDS

The above photographs illustrate four widely different designs.

tation, for which the purchaser must necessarily be prepared to pay.

A first-class chassis with a 4-cylinder engine in the 90 mm. class will cost about £450, and a 6-cylinder car of the same dimensions will probably cost about £650. To these prices must be added the cost of the coachwork, which may be anything from, say, £80 for a small open car up to £300 or £400 for a large and luxurious closed carriage.

UPKEEP

The upkeep charges in respect to the maintenance of a car are, in a sense, divisible under three heads. One group represents a fixed annual sum that is nearly independent of mileage and of the size of the car. Under this head comes the rent of the garage, for which it is obviously impossible to give a fixed price, as it may be anything from nothing to £20 or £30 a year. Many garage firms will house and wash a car for £1 a month on a yearly basis. The wages of the chauffeur, like the rent of the garage, may be nothing at all or a comparatively high figure, but in any case when a chauffeur is employed his wages, say £2 a week, represent a fixed charge that is independent of the car mileage. In some cases, owners give their chauffeurs bonuses according to the mileage accomplished without breakdown.

One of the few really definite fixed charges is the driving licence, but this only amounts to

5 shillings per annum. It may be obtained by anyone from the offices of the local authority of the district The chauffeur naturally obtains his own driving licence, but the employer of a chauffeur needs to take out a manservant's licence in respect to such employment, which licence costs 15 shillings per annum, and can be obtained from the post office.

When the car is first purchased it is necessary that it should be registered with the local authorities, the fee for which is £1; but having once been paid, the payment does not have to be repeated. The number that is issued at the time of the registration belongs to the car and not to the owner. If the car is sold, the number passes with it, and the change of registration of ownership is effected on application to the local authority and the payment of a fee of 5 shillings.

The above-mentioned taxes must not be confused with the revenue tax, which is payable annually at the post office. This revenue tax comprises the old carriage tax and the super-tax that was applicable to the use of a light locomotive. It is arranged on a sliding scale according to the engine power of the car, as rated by the bore and number of cylinders of the engine. It varies from 2 guineas upwards, the 80 mm. 4-cylinder class coming within the 4-guinea tax, while the 90 mm. and 100 mm. 4-cylinder cars pay 6 guineas. The revenue tax

may be regarded as coming within the second of the three divisions into which the upkeep charges may be divided. Its amount depends upon the size of the car, but is independent of the mileage.

In this same category should be placed the insurance premium, and also the annual sum written down against depreciation and repair. Both these items vary with the size of the car, but are independent of mileage. The insurance on a 15-h.p. car valued at about £500 will probably be in the order of 12 guineas per annum.

Having separated out the above charges in this way, there remains the direct cost of motoring under the head of petrol and tyres, which does, of course, vary both with the size of the car and the mileage run.

It is impossible to give very exact values under these heads. The price of rubber influences the price at which tyres are sold, and it is only necessary to recall the fluctuations in the last two years to recognize how widely the cost under this head may vary. The price of petrol has also appreciably altered, and may continue to do so. Apart from these external influences, there is also the effect of the difference between good and bad driving. A man who drives so that he seldom uses his brakes, or when using them always avoids skidding the wheels, will have an appreciably greater tyre economy than the man who is careless of these considerations and who takes his

car full speed over any and every kind of road. Also, the systematic inspection and repair of outer covers by vulcanizing them when they are cut may perhaps increase their life sufficiently to effect an appreciable economy on the year's up-keep.

Taking one car with another, however, the conditions in England are such that, broadly speaking, most motorists run about 10,000 miles in the year, and use two sets of tyres in that period. Big, heavy cars driven at high speed may need more than this, whereas a light car carefully handled might involve less expense.

With petrol there is perhaps not so much opportunity for marked economy in driving if the car itself is not in the first instance fitted with an economical carburettor and system of control. It must be remembered that the petrol is the sole source of power, and that in the petrol the latent energy is a limited and fairly definite quantity. Given equally economical engines, therefore, a higher petrol consumption in one than in another implies that more power is being developed by one engine than by the other, and from this increase of power the motorist is presumably deriving some advantage. Perhaps he may be riding in a more commodious carriage or travelling at a higher speed, but in any case the increased power is being expended somewhere or other for his benefit.

HOOD AND WIND-SCREENS FOR AN OPEN TOURING CAR

The above photographs illustrate the Auster wind-screens and hood, the former being designed to protect the front and rear passengers separately, and the latter being so constructed that it can be raised and lowered without assistance.

To this extent, therefore, the petrol consumption of the car is a measure of its useful power to the motorist, and the price that he pays under this head will be in direct proportion to the advantages received. Some cars will travel 20 miles to the gallon. A few will go further, but the majority will go less far. It depends entirely on the weight of the car, and to a large extent on the speed at which it is driven.

With a 4-cylinder 80 mm. car it should be easily possible to do a year's motoring of 10,000 miles on an expenditure of £50 in tyres and £40 in petrol, which makes the two direct charges equal to £90, or about 5 shillings a day for a 26-mile journey repeated every day of the year. The cost per mile thus works out at about 2¼d., which is less than a first-class railway ticket, even when the owner travels singly, and is proportionately reduced if the car carries four passengers, as more often than not will be the case.

CHAPTER II

TOURING

A MOTOR-CAR is not a possession that can be ignored. It is, in fact, likely to alter a man's mode of living in more ways than one, and it is of some consequence both to the individual and to the community that its influence should be advantageous.

Apart from its direct utility as a means of daily locomotion, the motor-car offers unrivalled opportunities for sport and travel, but it is more particularly with the latter that this chapter is concerned. The motorist, unlike the tourist by rail, finds the best part of his holiday in the journey itself. It is seldom that a train journey is really alluring. The best of scenery is never so realistic or picturesque when seen through the framed glass of a railway carriage window as it is from the seat of an open touring car. Moreover, the train runs to a schedule that is not devised for the convenience of those who would contemplate the beauties of Nature *en route*, whereas the motorist can stop by the wayside as often and as long as the fancy takes him.

First and foremost then in the art of using a car

WITH THE CAMERA AND THE CAR

A Kodak study of thatched cottages on a typical English by-way

to the best advantage stands the necessity for avoiding the "time-table journey" on a trip that is intended for pleasure.

One great physical advantage that the car possesses over all other modes of locomotion save pedestrianism is that it takes you absolutely from door to door. There is no vehicle of any description that enables you to travel so comfortably and so quickly from your own home direct to the very heart of your destination as the motor-car, and he who gains most from his motoring is he who most completely realizes this quality in his manner of using the car.

Rushing pell-mell along the highways of the land is undeniably a species of good sport, given always the conditions that make for safety in respect to other road users, but it is not the kind of motoring that produces the most lasting pleasure. If such a mode of travel becomes an obsession it degenerates into habitual "road-hogging" of the kind that happily is now for the most part only a reminiscence of the past in England.

It is, of course, necessary and pleasant to travel fast at times, and such driving, in discretion, is neither dangerous nor inconvenient to others.

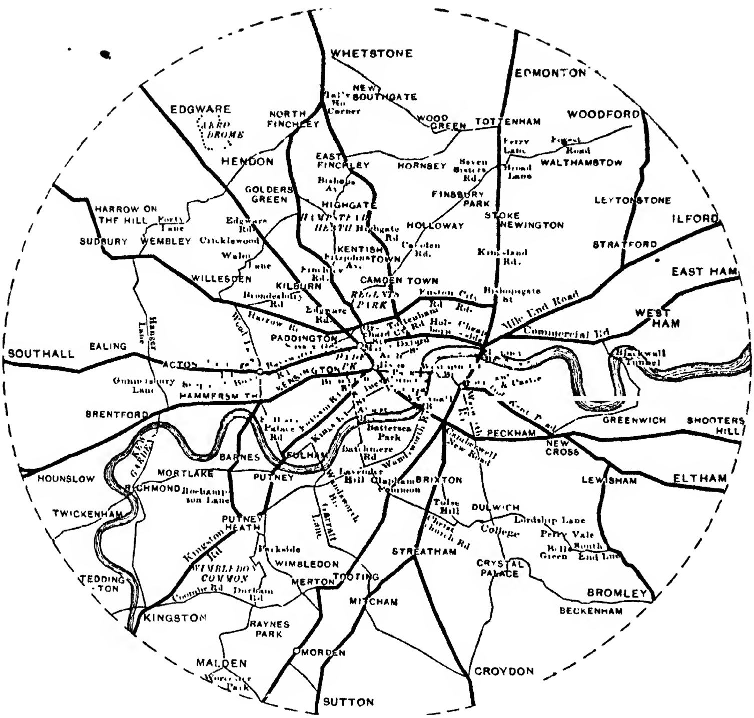
In general, I have found that fellow-passengers seldom really appreciate fast driving as much as the habitual high-speed driver is pleased to imagine; indeed, it is much easier for a chauffeur,

whether amateur or professional, to acquire a good reputation by systematically driving at moderate speeds than by the over-frequent display of feats of fineness performed at projectile-like velocities. Many a man who drives wonderfully well in his own estimation is a sheer source of secret terror to his friends in the car.

Regarded merely from the standpoint of politeness to one's guests, it is only proper that one should consider their feelings, and particularly those of passengers comparatively unaccustomed to motoring. There are those, I know, who only ask to go faster, but for such an one there are a score who would much prefer to go more slowly.

But these considerations appertain more to the art of driving than to the art of touring as such. I have said that the great point to be achieved is to use the car to take you actually to the very places that you want to see, and that in the use of the car for touring you should, therefore, avoid the "time-table" journey.

In place of the schedule of times there should, however, be a schedule of places, and this may best be prepared in the form of a map. Its preparation involves reading up the country in advance, which, in itself, is a recreation, for the encouragement of which motoring deserves much indirect credit. There is nothing so dull as reading about places that one is never likely to see,



Auto Key-map illustrating the principal roads through London, and for a radius of ten miles round.

yet nothing more attractive than to learn something about those that one is about to visit. As a consequence of this reading, which enhances so much the anticipation of a motoring holiday, an interest is engendered in many small places that ordinarily would have escaped notice. Moreover, an entire district by degrees discloses the romance of its history to the mind and the heart is satisfied merely to be there.

Some people regard England as a great museum, and flit from object to object, guide-book in hand, forgetting the while that the very floor they walk upon is a mosaic of far greater human interest than any monument it may support. Well may those who travel by rail seek inspiration from a gravestone or a ruin, but you who go by car can see the very scenes of which these records are but the index marks upon the roll of time. Surely you lose the best of England if you fail to sense the romance with which old history has saturated our once virgin soil, to admire the simple beauty of Essex with the eyes of Constable or to thrill on Culloden Moor with the heart of a Scot.

To see everything is difficult even for an Englishman of leisure, and impossible for the visitor with limited time. Those who come to England from abroad must tour with discretion if they would see even a fraction of what is best worth while. It is only by taking pains in advance that anyone can secure the subsequent ease and enjoyment on

The Beauty of Scotland

In the foreground is an Argyll car from the factory at Alexandria, near Loch Lomond.

the journey that it is the object of a motoring trip to attain.

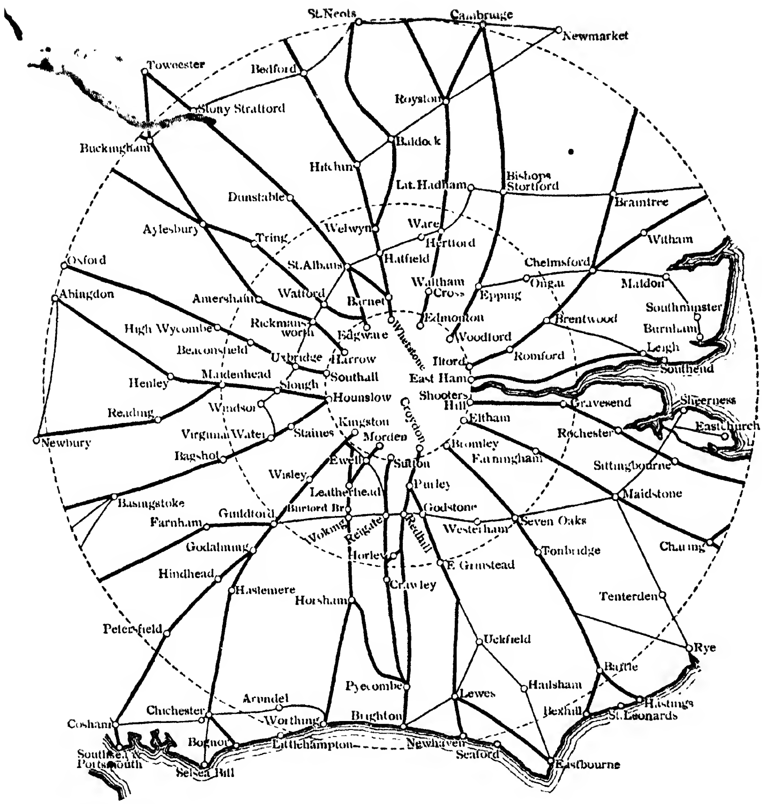
Nothing, for example, adds so much to the pleasure of motoring as a good hotel. There are many such in England, but they want finding; those who do not know their whereabouts frequently have to put up with the poorest sort of accommodation while the best awaits them within a mile or two. Much the same may be said with respect to places that are best worth seeing. Sights that would long be remembered may be passed by within a stone's throw while travelling persistently along some highway that has little to prevent it from being readily forgotten. Mileages, too, are deceptive in England, for if the roads are good they are also confusing, and few drivers know every part of England.

These facts all point to the desirability of making plans in advance, provided always that there is no intention of trying to keep to a schedule time-table on the journey. By making plans, I mean reading all the interesting literature that you can find about the district in which you are likely longest to remain. By making plans, I also mean the study of maps, the preparation of suggested routes and the gradual collection of useful and interesting information from fellow-motorists during the course of the year, all of which is noted and made use of when the time comes for the journey.

Maps form a fundamentally important part of the preliminary preparation of a tour. *En route* they are of far less use, for a motor-car travels too quickly for the average map reader to gain much assistance from its study in motion, and most drivers prefer to go ahead down the road they have chosen, on the off chance that it leads in the right direction, rather than pull up to study the sign-post by the aid of the map.

Signposts seldom indicate the names of the towns that one has in mind, and in many localities they are almost useless to strangers. For this reason it is of the utmost advantage to get to know a district thoroughly if it is one that you visit frequently, or reside in for long periods. Complete familiarity with the byways of the home county not only adds immeasurably to the pleasure of an afternoon jaunt, but it has a very practical value in the manner that it facilitates the beginning and the end of a long journey. To know all the cross-country roads within a radius of twenty miles of one's home is, particularly for those who live near cities, an immense help in touring, and it is well worth while spending spare afternoons learning these cross-cuts thoroughly.

Taking a cross-cut in a strange district in the hope of saving time almost always ends in disappointment, for roads never actually look as the mind creates them from a study of the map, and although most people find it easy enough to



Auto Key-map showing the principal highways radiating from the ten-mile circle.
This map is a radial continuation of that on page 33.

remember places that they have once seen, even after long absence and when there is no special landmark, yet almost everyone will go astray the first time that he attempts a new cross-country journey.

It is always advisable to employ spare time for learning routes, because one very important point is to retrace one's track whenever one has gone astray. Otherwise, the experience is not only valueless but very likely to be misleading on a future occasion. If one is pressed for time, however, such tactics seem out of the question, although in truth there are many occasions when it would be far better to go back than to go forward.

In the planning of long journeys, it is very important to study the roads carefully, and to obtain as much advice about them as possible. The absence of straight roads in England increases the difficulty of reading a scale map, and it is an excellent plan, therefore, to prepare private key-maps showing the route diagrammatically as a straight line between the various more important places. A series of such key-maps was prepared by the *Auto* some while ago, and has proved very popular among motorists. Some reduced reproductions of these maps are included among the illustrations in this book. One of them shows the principal exits from London out to a radius of ten miles. Another shows the continuations of

Arundel Castle

A Kodak study of one of the best-known "pictures" belonging to the motorists in the southern counties.

these roads from the ten-mile radius. Such maps as these, once made, serve for all time, and so it is worth while keeping the key-maps that one prepares. It must be understood, of course, that the key-map merely supplements the scale map, as it is the essence of the key-map that it should contain nothing beyond the mere line of route.

Among the key-maps illustrated in these pages is one that gives a specimen tour that has often been recommended in the *Auto* for American visitors to England, and it may be interesting briefly to review the route. It starts from London and sets out via the famous old coaching highway to Portsmouth. One of the best all-round roads in England, the Portsmouth road affords one of the easiest exits from London, and, as a highway, it possesses character that will cause it to be remembered long afterwards when many minor details of the journey are forgotten.

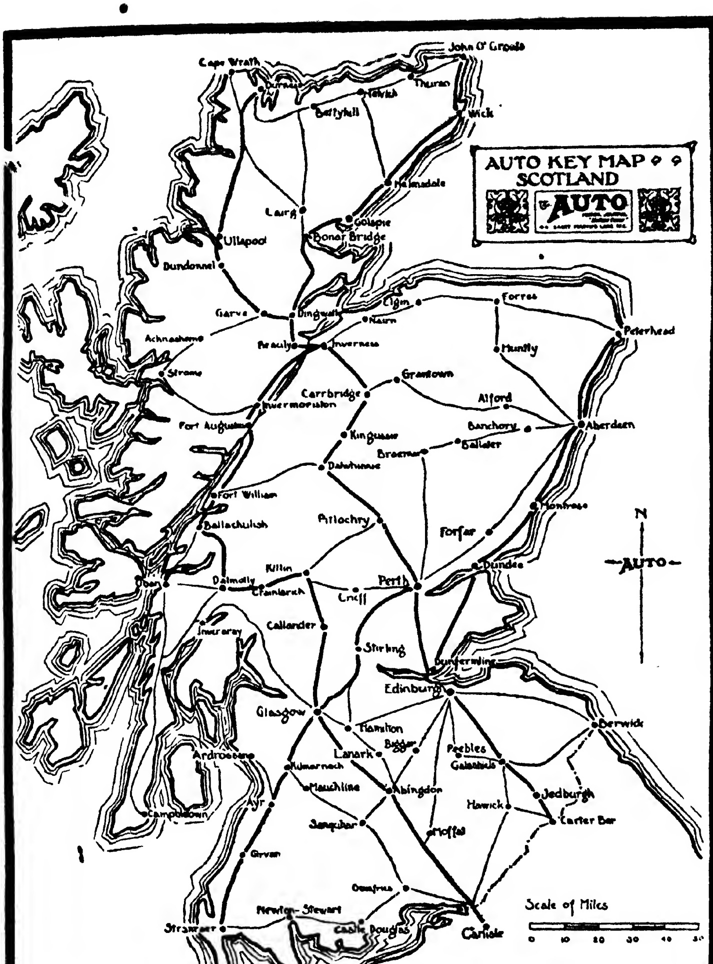
As a late start is a very common occurrence with motorists, the well-known "White Lion" at Cobham or the "Hut" at Wisley serve as excellent stopping-places for lunch. Further on is Winchester, where those who start early will get their midday meal, and where, also, early or late, those who pass through it for the first time will certainly be delayed by much sight-seeing among the historic relics of the past.

From Winchester it is a pleasant run down into

the New Forest, where there is an excellent hotel at Lyndhurst. This is a district that is full of attraction, and several days can well be spent in excursions round the neighbourhood, for every part of the New Forest is beautiful.

It is evident from the shape of England that the counties of Devon and Cornwall are inconveniently situated for those who desire to economize mileage in the form of a circular tour. They are, in fact, essentially counties that should be set apart for a separate holiday. To include them in a circular tour is to occupy relatively much time in one locality, for having gone into Cornwall it is necessary to come out again by much the same road, and the better plan for the visitor making a circuit of Britain is to cut across the New Forest north-west through Salisbury to Bath, which is, of course, a city of unusual historic interest.

From Bath, the objective is North Wales ; but in order to skirt the Bristol Channel it is necessary to make a detour, and the best route is that through Cirencester, Gloucester, Ross, and Hereford, in which delightful old-world country town there is excellent accommodation for the night. In Hereford, one of the sights is the cathedral, and those who go there should not fail to see the famous chained library, as it is one of the best in existence. Herefordshire, particularly the Wye Valley, is essentially a country for the leisured motorist, for many are the excursions worth



Auto Key-map to the chief Scottish highways.

making, and great is the beauty of many of the views to be seen.

Travelling north from Hereford, the road leads through Leominster, Church Stretton, and Shrewsbury, to Llangollen, a very small place, but very attractive withal. The Hand Hotel there is an inn with a past, and possesses besides a singularly charming outlook over one of those noisy little rivers that keep you awake o' nights by their incessant music as they cascade over the rocks and stones.

Llangollen is upon the great Holyhead highway to the Irish steamers. It leads also direct into the Welsh mountains and incidentally to a little place called Pen-y-Gwryd on Snowdon, where there are a good hotel and wonderful scenery. Thence north to Bangor, and thence east along the coast through Colwyn and Abergele will take you to Chester, England's one and only "dead city."

And so from scenes that are beautiful one comes at last into the Black Country with its reminder that the world we live in is not itself made more lovely by the handiwork of man. Up through Warrington, Wigan, and Lancaster, the road to the north leads through some of England's busiest industrial centres; but, at last, the wayfarer emerges on to the lake side at Windermere, which is the centre of this inland resort.

No one who visits the Lakes should omit to

The Old-world Village of Holywell

A Kodak study near St. Ives, Huntingdon.

take a few at least of those fascinating circular drives with which the country hereabout abounds, and in particular is the road from Ambleside up on to Kirkstone Pass and thence along by Ullswater as far as Penrith worth following, for it is one of the most beautiful in the land, and especially so in the quiet of a summer's evening.

Carlisle, the next stopping-place, is, as it were, the gateway to the north. Many motorists who leave London by the Great North Road, which itself runs up to Edinburgh direct, prefer to branch off so that they perform the latter part of the journey into Scotland via Carlisle. By either route the country north of Carlisle is wild and in places desolate in the extreme. Here, however, in this very wilderness, is one of the great charms of scenic England. There is, perhaps, no country in the world that embraces so much variety on such a realistic scale in so small a space.

It is a very good plan to make for Edinburgh from Carlisle by working across through Hawick and Galashiels. To the visitor from overseas this will have the additional advantage of causing Edinburgh to be the starting-point of the Scotch circuit, and most of those who go to Scotland for the first time will think it more appropriate to do this.

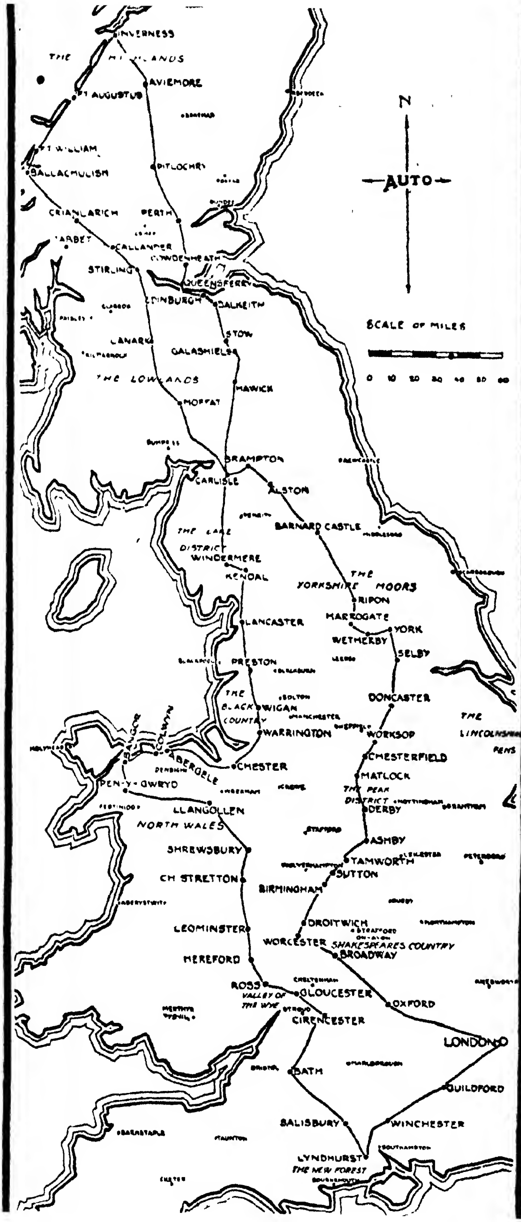
From Edinburgh, the car can be taken over the Firth of Forth on a ferry, so as to enable a

route due north to be followed through Cowdenheath and Perth to Pitlochry where there is a Hydro that makes the place a good halting-point for the night.

Continuing north, Inverness is reached at last, and here the motorist with only a limited amount of time at his command will probably decide to begin his southern journey. As a glance at the map of Scotland shows, the mainland is divided diagonally south-west from Inverness by the Caledonian Canal and the lochs that join it together. The road that runs down by the side of Loch Ness past Fort Augustus to Fort William is, I often think, the most beautiful in the whole tour, and I can wish none who may be making this trip greater good fortune than to have the blessing of a perfect summer's day for its journeying.

From Fort William, the chosen course to Stirling runs south-west by Ballachulish Ferry, across which the car can be taken, which is more than can be said of some of the Scotch ferries in the less frequented districts of this much dissected country.

It is not easy to plan a tour through Scotland because the nature of the country and the disposition of the roads render an economical mileage somewhat difficult to arrange. Scotland is essentially a country that should be visited separately, but from some points of view the



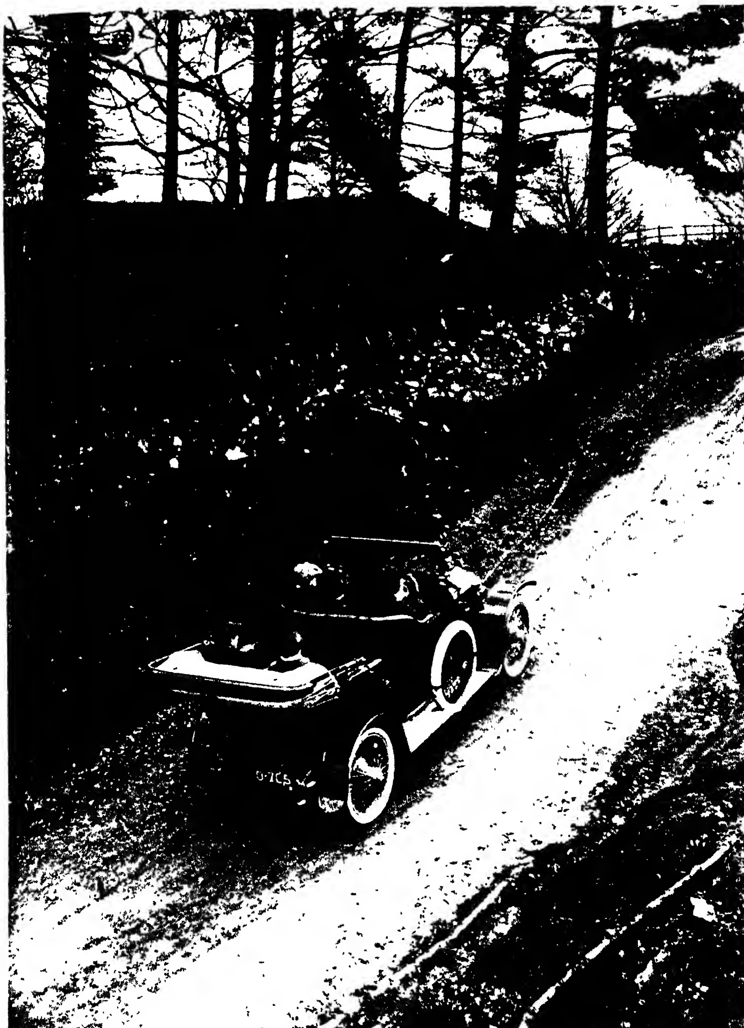
Auto Key-map giving a convenient route for a circular tour through England and part of Scotland.

circuit indicated would serve well enough as a basis of a more extended trip, for most of the additional mileage would consist of routes jutting out from and returning to the main points indicated.

Scotland, it must be remembered, is always crowded during July and August, and motorists who desire to travel in a casual way would be well advised to go there in June, which is an altogether charming month for the country. If this is too early, then it is advisable to book rooms in advance. In the mountains, it is always desirable to be thoroughly prepared for rain when touring in an open car.

Coming south from Stirling via Lanark and Moffat to Carlisle, the journey will seem of small interest and great length compared with the other sections allocated to a daily route. From Carlisle it will be desirable to strike across towards the east so as to enter the Yorkshire district. Here, Harrogate offers suitable head-quarters for tourists engaged on excursions over the moors and into the many quaint old-world villages in that part of the country.

York itself, it is interesting to remark, does not lie on the old and original Great North Road. Nowadays, of course, the highways are so numerous and so good in many places that there is no apparent difference between the road via York and the road that misses York; it is merely a



Motoring Sport: Hill-climbing

A Wolseley with four passengers climbing a really steep bank.

matter of interest to know that even in the early days the main highway was not itself diverted by the early importance of the old capital city. There has always been considerable controversy as to which is and which is not the Great North Road of tradition in the many places where that highway now divides only to rejoin at some more distant point. Not only is it a matter of controversy, but of some confusion too, for more than one good motorist has lost his way while trying to follow this perhaps the most famous, but in some places the least well defined of all our highways.

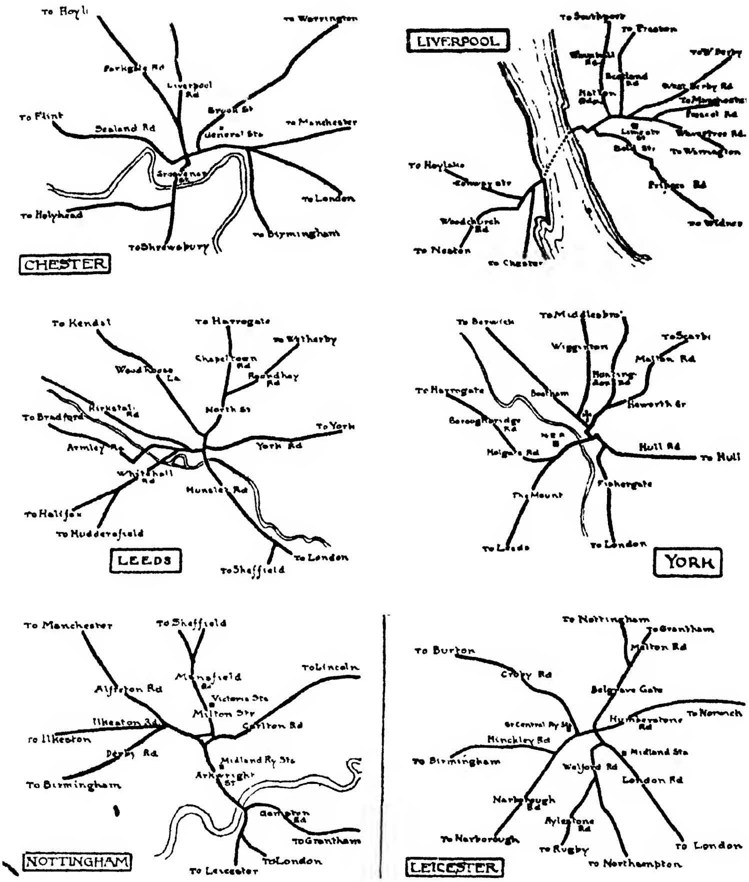
Having visited York, there follow the less interesting towns of Selby, Doncaster, Worksop, and Chesterfield before Matlock, in the heart of glorious Derbyshire, gives the tourist another happy hunting-ground. Then down through Derby itself, through Ashby, Tamworth, Sutton, and Birmingham to Droitwich, where are the famous brine baths, and the doubtful delights of swimming in water in which you cannot sink but which will leave you with a saline deposit on your body that will call for exercises almost as vigorous as those associated with the revival of the apparently drowned in order completely to remove.

Worcestershire and Warwickshire are two of the most attractive counties in England, but then one is inclined to say that of almost every county that we possess, for each in its way has delights that

are entirely satisfying to the lover of beautiful scenery. The route chosen lies through Worcester and Broadway, the latter being one of those delightful little villages lying at the foot of the hills, and having one of those fascinating old inns, the Lygon Arms, wherein is usually to be found a quantity of interesting old china and furniture.

The next place of great importance on the return journey is Oxford, but needless to say there are many other towns within easy reach that would well repay a visit. Indeed, the entire circuit is but a solitary track through a garden of much loveliness, and at the best it can only serve to give the stranger a slight idea of the infinite variety and scenic charm that our island possesses. Whole counties, to say nothing of the whole *country* of Ireland, have been omitted, but it is impossible to include everything in one circular tour.

Before closing this chapter it seems proper to make some further reference to the sporting side of motoring, for the modern car owes its present perfection more to the early influence of this element than to almost any other factor. True, the sporting element has often had a strong flavour of commercialism, but the fact remains that from the competitive use of cars, whether by the trade or by *bona fide* amateurs, much was accomplished towards the rapid evolution of a reliable and refined vehicle that could not other-



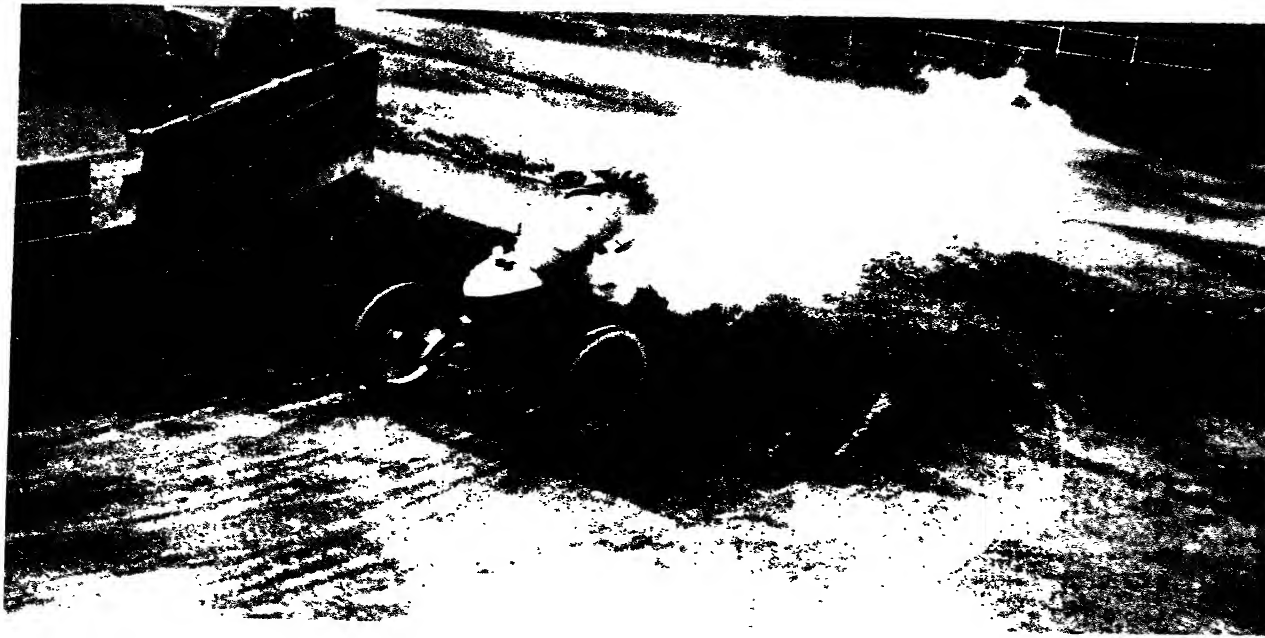
Auto Key-maps to towns. Local maps should be obtained and sketch plans like the above prepared in advance of the tour.

wise have been attained in the same short space of time.

The early road races, and particularly the Gordon-Bennett Race, which was the Derby of motoring in the early days, taught manufacturers more in a few hours about the defects of their cars than they would ordinarily have learned in many months. It was expensive to compete in such events, but at the worst it was the purchase price of experience, and at the best there was always the chance of victory and its reward of an unrivalled advertisement.

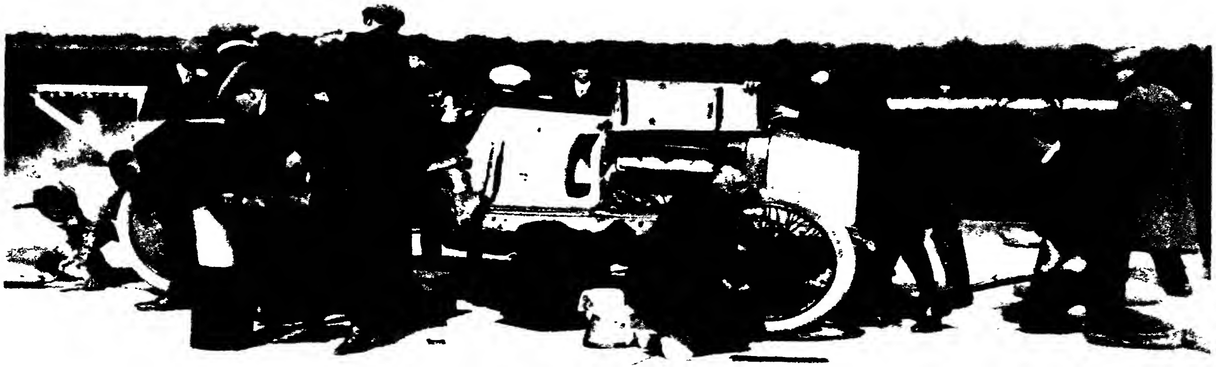
When Brooklands track was built, manufacturers were surprised to find that the maintenance of high speeds thereon punished a car even more severely than ordinary road racing. On Brooklands, a car is driven all out from start to finish; there are no corners where it is necessary to slow down or long descents where the engine can be given a comparative rest. These brief respites in road racing are an important consideration, or rather, to put it the other way, their absence from the conditions of track racing at Brooklands is a factor that has disconcerted many a driver and many a car designer who has wholly supposed that the only difficulty would be to get an engine to turn fast enough.

At high speeds, Brooklands track gives the car a thorough jolting, and will shake loose any parts that are imperfectly fastened. Continuous



Motoring Sport: Road-racing

A Calthorpe car being driven by Lewis round the St Martin corner near Boulogne.



"*Auto*" *Copyright Photograph.*

MOTORING SPORT: RECORD-BREAKING

An interval in the Argyll record-breaking run of 1070 miles in fourteen hours at Brooklands on May 27th, 1913. The car was driven alternately by W. G. Scott and G. Hornsted. Its engine was a 15-h.p. 4-cylinder single sleeve-valve motor, having a bore and stroke of 80 by 130 mm. The rear axle was worm-driven.

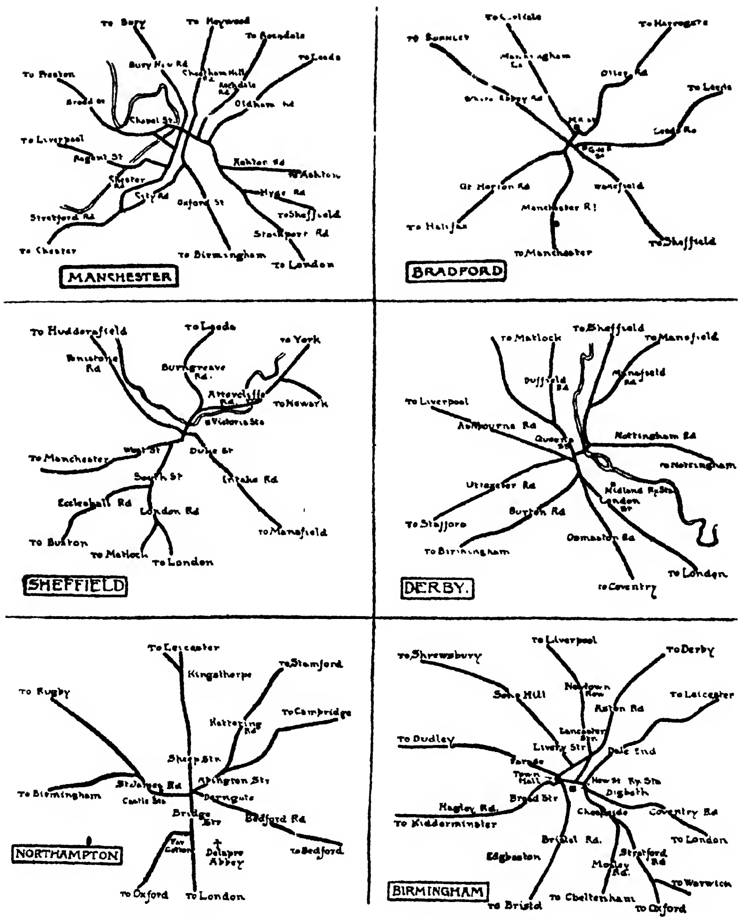
working at high pressure taxes the engine to its utmost, and speedily brings to a climax any defects in the lubrication or cooling systems. Tyres, too, are punished very severely, especially by those drivers who do not take sufficient pains to study the exact position on the banking that suits their speed.

The building of Brooklands was a remarkable enterprise for which Mr. Loche King deserves much credit, for it was a costly undertaking and held small promise of commercial success. Motor racing as a spectacle was doomed from the first to have very limited attractions, because the high speed of the cars renders a really close finish a mere accident. If a car is travelling at 70 miles an hour, it covers approximately a hundred feet in a second, and although to be only one second behind the winner may seem a pretty near thing in a race that has perhaps occupied a quarter of an hour, yet, from the standpoint of the spectator who sees the two cars several lengths apart, the second machine appears to be hardly in the running. Moreover, Brooklands itself is so large, being over three miles to the lap, that high speed in the absolute is hardly appreciated. Indeed, a car has to run so smoothly in order to be capable of being driven at speeds in the neighbourhood of a hundred miles an hour, that the spectacular effect of these sensational velocities is almost altogether lost to the observer

at a distance. Looking down from the members' bridge as the cars hurtle underneath on the steep banking is, however, a sight that is worth going far to see.

As was forecast from the first by Colonel Holden, who designed the banking, Brooklands has attracted far more attention as a ground for record-breaking than as a race-course in the ordinary sense of the term. There is, in fact, at the time of writing, a very strong rivalry among some of the leading firms to beat each other in establishing new records for speed. Some very remarkable performances that have been more than creditable to both man and car have been accomplished at Brooklands. One of the first was Mr. S. F. Edge's remarkable feat of driving for 24 hours on end. During the night he had lamps placed around the track, and so he succeeded in keeping his Napier car up to an average speed of 65·9 miles an hour, thus completing a journey of 1581 miles. Owing to inconvenience to residents in the neighbourhood caused by the noise at night, further 24-hour records were prohibited; but since that time some still more remarkable 12-hour records have been created, while attempts on the hour record, which stands at well over 100 miles, are matters of comparatively common occurrence.

Owing to the legal speed limit, competitive events on English roads are practically out of the



Auto Key-maps to towns. A useful method of facilitating progress through unfamiliar places.

question where speed over a long distance is a factor of prime importance, but several extremely interesting and very enjoyable competitive hill climbs have been organized by the Royal Automobile Club and by the various provincial clubs, and a few of the more important of these events still continue to take place annually, and they always attract not only a good entry list but quite a large number of spectators.

"Auto" Copyright Photographs.

MOTORING SPORT: RACING AT BROOKLANDS

1. Lining up for the start.
2. Approaching the banking from the fork.
3. Cars on the banking as seen from the Members' Bridge.

CHAPTER III

THE FUNDAMENTAL COMPONENT PARTS OF A CAR

ANY complete car consists essentially of chassis and coachwork. It is with the component parts of the former that this chapter deals. The chassis contains all the mechanism, it can be driven along the road, and it is a vehicle in everything save adequate accommodation for the passengers.

It is convenient to regard the elementary construction of a motor-car chassis as comprising three groups of mechanism. Firstly, there is the frame, which is attached by springs to its four wheels, two of which are controlled by steering mechanism, while the other pair carry brakes.

In this group we have the basic requirements of a vehicle. It remains to equip the frame with an engine, and to provide the engine with a system of transmission for communicating its power to the road wheels.

The engine is essentially a self-contained unit. Those used on motor-cars have been developed on special lines to suit their particular purpose, but as power plants they are capable of operating

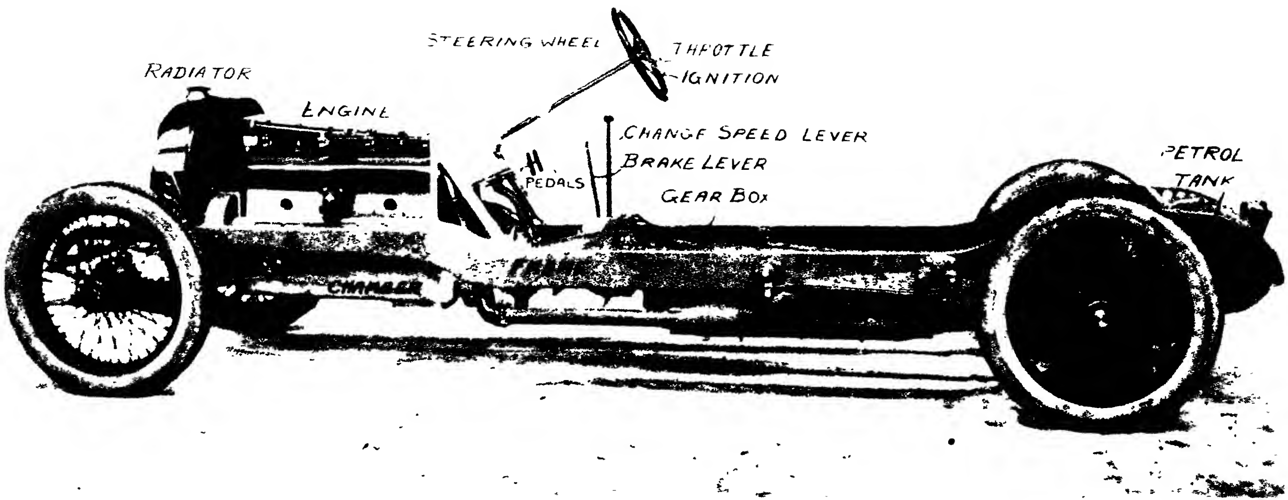
independently of the remainder of the chassis, and they might be used for extraneous purposes, such as driving electric light dynamos or water pumps, as indeed they are in some instances.

On the other hand, the transmission is part and parcel of the car. In the form in which it is employed in automobile construction it has no independent utility.

There are, *au fond,* three units in the transmission system of a car: one is the clutch, another is the gear-box, and the third is the final drive.

Of these three members, the clutch is situated nearest to the engine, and its purpose is to facilitate the instantaneous disconnection of the transmission system from the engine. When the car stops, the engine does not necessarily stop. One does not stop a petrol car as one stops a steam-car by stopping the engine; on the contrary, the engine on a petrol car runs while the car is temporarily at rest. Of course, if the car is to remain at rest for more than a minute or so, the engine is stopped in order to save petrol. Similarly, when descending a long decline, the engine is usually switched off by the thoughtful driver.

In most cases, the determining factor in the question as to whether the engine shall or shall not be stopped during a temporary halt of indefinite duration is whether it is easily started again. The introduction of automatic starting mechanisms will thus tend to make drivers stop



SIDE VIEW OF A SIX-CYLINDER SHEFFIELD SIMPLEX CHASSIS, ILLUSTRATING THE DISPOSITION OF SOME OF THE PRINCIPAL COMPONENT PARTS

their engines as a matter of course, whereas now they are more often left running.

Although the clutch is the mechanism by which the engine is connected to and disconnected from the transmission, its normal condition is one of engagement, even when the engine is running and the car is at rest. Provision is made in the gear-box for permanently interrupting the continuity of the transmission system and so the clutch is only used temporarily for this purpose.

A powerful spring is used to hold the two members of the clutch in engagement, and a pedal is conveniently placed so that the driver can separate the halves of the clutch by the pressure of his foot. It is fundamentally necessary that a clutch should be instantaneous in its disengagement and gradual in its grip.

If the engine, which is already running while the car is still at rest, were abruptly and positively coupled up to the transmission, the car would be jerked suddenly forwards to the great discomfort of the passengers. Also, the machinery might be unduly strained or even broken and the engine would be very likely to stop. One of the primary purposes of a clutch, therefore, is to provide means for effecting the connection between the engine and the transmission progressively.

It is mainly on the delicate control of the clutch-pedal by the driver that this progressive engagement depends. Some clutches are "fool-proof"

to the degree that the foot may be suddenly slipped off the clutch-pedal without a resultant jerk, but in the majority of cases, and particularly with old cars, the smooth starting of the vehicle appertains to the driver's art.

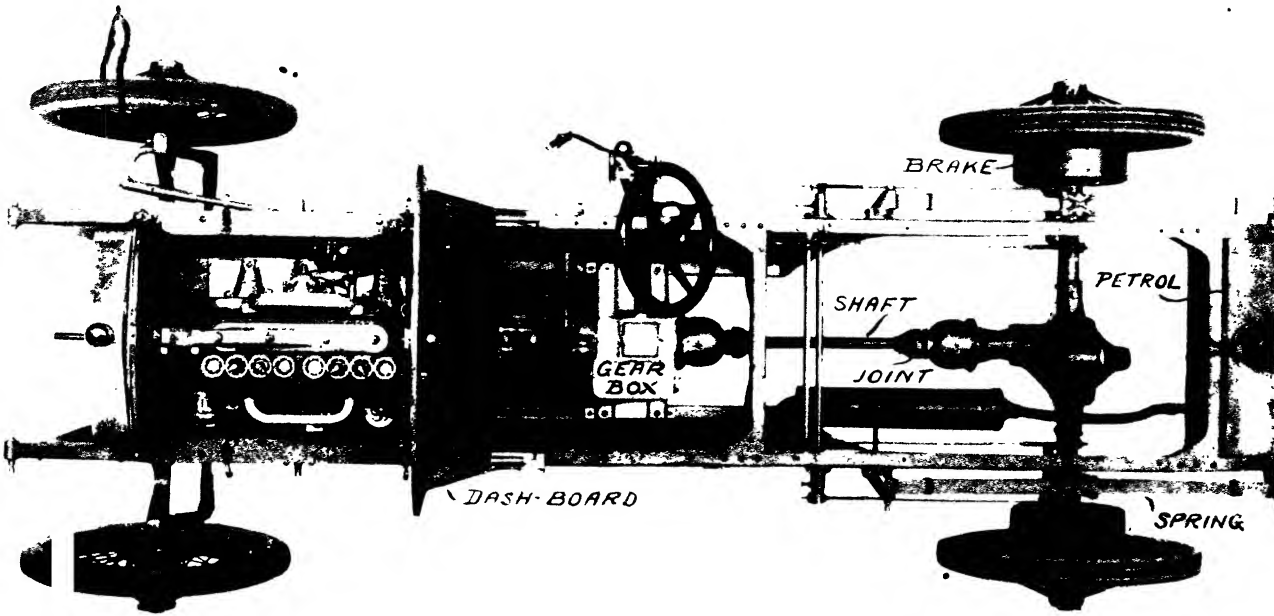
One of the two parts of the clutch is permanently connected to the engine, the other is permanently connected. to the change-speed gear. In some designs the gear-box is adjacent to the clutch, in others it is further removed towards the rear end of the chassis, in some cases it is to be found incorporated with the rear axle.

In either case its purpose is the same, viz. to provide a selection of gears of different ratios through which the engine may drive the car.

A petrol engine on an automobile is somewhat in an analogous position to a man riding a "push-bike." The cyclist finds that he can work most effectively when he is pedalling at a certain rate, and he has his bicycle geared to suit his ability. In hilly districts, a rider who is accustomed only to the flat is continually at a disadvantage through being unable to pedal as fast as usual, and his speed on the ascents is *disproportionally* slow.

In order to remedy this defect, most modern bicycles have three speed gears incorporated in their rear-wheel hubs, and by the aid of this mechanism the rider is able to gear the machine to suit the conditions *en route*.

In the same way, the petrol engine on an auto-



P VIEW OF A FOUR-CYLINDER STRAKER SQUIRE CHASSIS, ILLUSTRATING THE DISPOSITION OF THE PRINCIPAL MEMBERS

Tl gine and the gear box are supported on an under-frame The propeller shaft is exposed, but the universal joints at each end of it are enclosed in oil-tight casings. The petrol is carried in a tank at the rear enc of the frame, and is forced to the carburettor by air pressure

mobile works best at a certain rate of rotation, and in order to enable it to maintain its revolutions, the driver " gears " his car to suit the prevailing gradient by " changing speed " while the car is running.

For this purpose he has a lever convenient to his hand, and with this he moves the mechanism inside the box so as to alter the ratio of the revolutions of the engine per revolution of the road wheels. On the level, the engine may perhaps make three revolutions for one revolution of the road wheels, when climbing a steep gradient, the ratio may be, say, twelve to one. The exact ratio depends on the weight of the car ; thus a heavy limousine is lower geared than a sporting two-seater.

Modern practice is to fit a gear-box containing either three or four alternative " speeds " in addition to the " reverse " that enables a car to be driven backwards. The provision of a " reverse " is required by law, besides being an essential convenience.

When the car is at rest, the normal condition of the change-speed mechanism is such that all the gears are disengaged. Under these circumstances, the lever is said to be " in neutral," and the clutch may be engaged with the engine running without starting the car.

Whenever a gear is engaged it is essential that the clutch should be disengaged if the car

is to remain at rest. If the clutch is engaged when a gear is "in," the car is thereby set in motion.

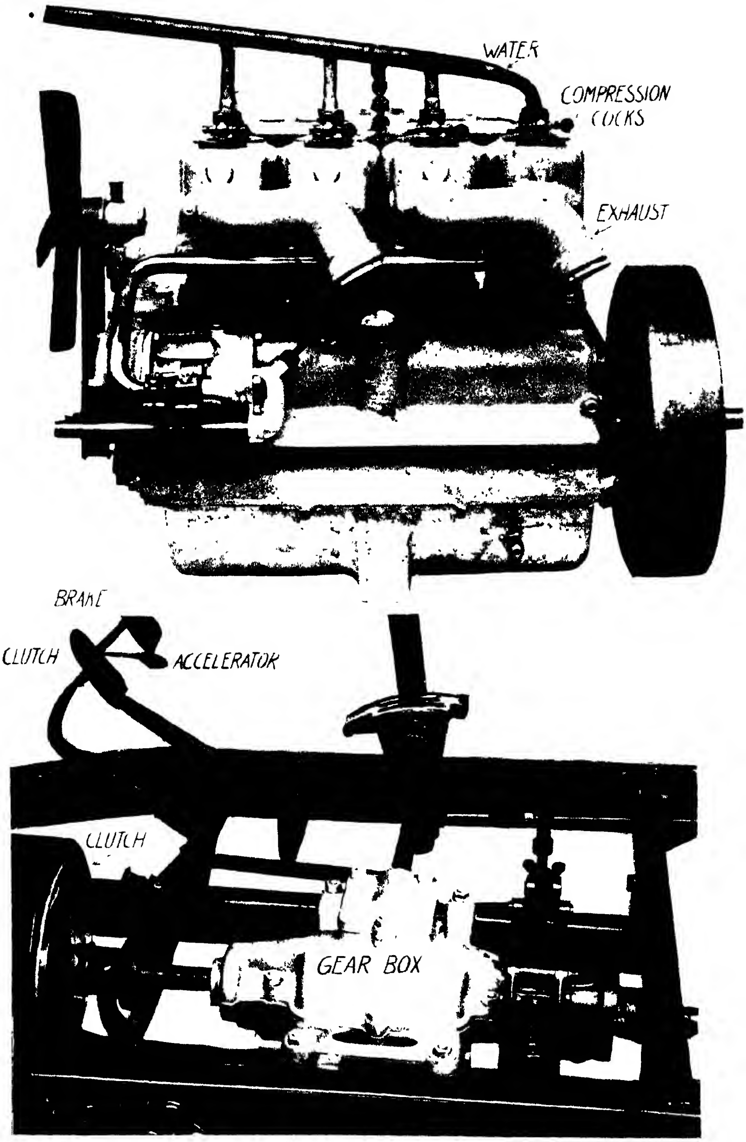
The clutch is also disengaged as a preliminary to gear changing, and it is held "out" during the movement of the change-speed lever. When the gear has been changed, the clutch is re-engaged by gently diminishing the pressure of the foot on the clutch-pedal.

Whatever "speed" may temporarily be in use in the gear-box, the rotation is ultimately transmitted to the shaft that constitutes the "final drive." In modern design, the final drive is a longitudinal shaft called a propeller-shaft, which engages with the rear axle of the car either by means of a bevel or a worm mechanism.

Formerly, it was customary to transmit the power independently to the two rear wheels by means of chains. The noise of the chain drive was responsible in the main for the universal adoption of propeller-shaft transmission to a bevel-driven live rear axle. More recently, however, the bevel drive itself has partly been ousted by the greater facility with which the worm-driven axle can be rendered silent in operation.

Whether it is a worm or a bevel, however, the purpose is the same, viz. to transmit the rotation of the transmission shafting through a right angle to the axle carrying the road wheels.

Two adjuncts of the final drive that are essential



THE ENGINE, CLUTCH, GEAR-BOX, AND FOOT-BRAKE ON A SMALL AUSTIN CHASSIS, ILLUSTRATING A TYPICAL AND STRAIGHTFORWARD METHOD OF CONSTRUCTION AND ASSEMBLY

The engine, with its accessories, such as fan, water pump, etc., forms a complete unit. It also carries the fly-wheel and the clutch contained in the fly-wheel. It is supported on an under-frame below the level of the main frame, and this same under-frame supports the gear-box. Immediately behind the gear-box is the foot-brake.

to the satisfactory working of the car are the universal joints and the "differential."

The universal joints are the couplings that connect the propeller-shaft to the gear-shaft and to the pinion-shaft driving the back axle. They permit the propeller-shaft to lie obliquely to the axis of the other two shafts, a condition that is essential because the axle is continually jumping up and down when the car is traversing rough roads.

Sometimes there is a universal joint at each end of the propeller-shaft, sometimes there is one only at the upper end immediately behind the gear-box. Of the two systems, the former is designed to give a more uniform rotation to the axle, but the latter is associated with other structural features that also have their advantages. Engineering at its best is, of course, only a compromise: perfection, even when apparently within reach in one direction, generally brings in its train some other consideration that argues against a merely one-sided solution of the problem.

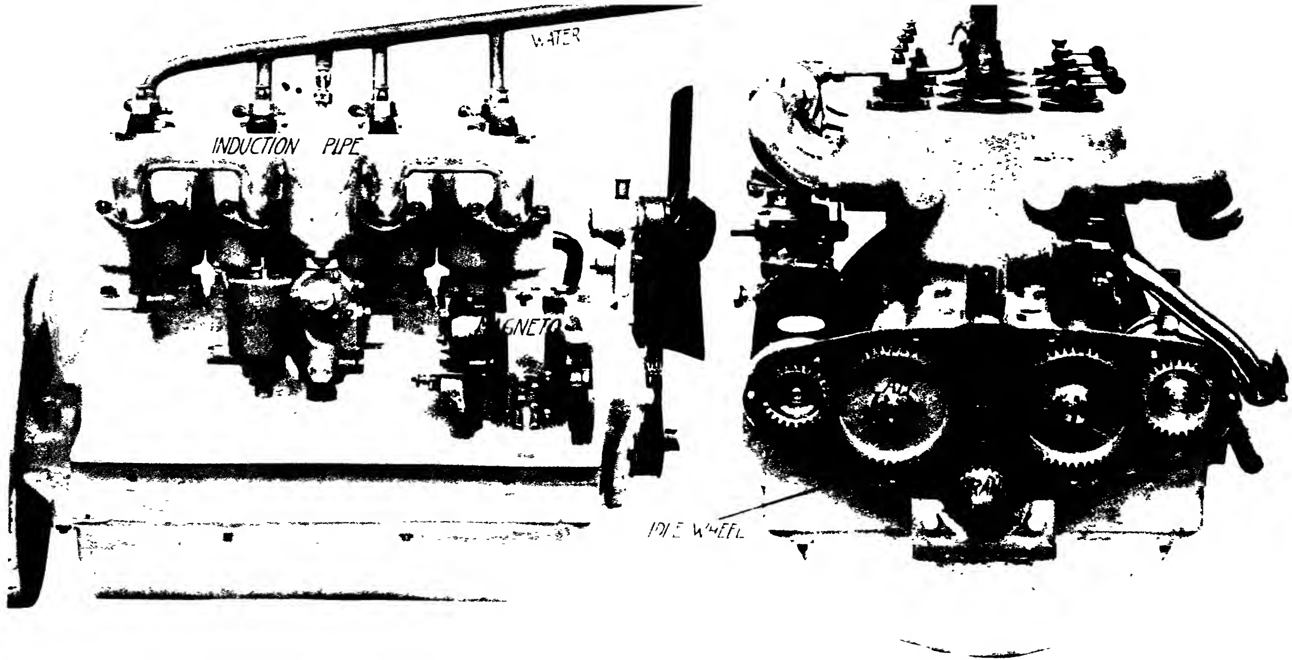
In addition to the universal joints in the propeller-shaft, one and sometimes two are usually fitted between the clutch and the gear-box in order to facilitate alignment of the shafting. When there is only one joint, it should be regarded merely as a coupling for convenience in the assembly of two separate members. Obviously, the shafts thus joined must either be truly in line

or they must lie obliquely to each other. In the latter case, the rotation of the driven shaft is slightly irregular. When two joints are fitted, the driven shaft may be parallel to the driving shaft, but displaced from axial coincidence by only a small fraction of an inch. This is the kind of tolerance that is more likely to be useful in chassis erection, and the presence of two universal joints transmits uniform rotation to the driven shaft.

In some designs, the engine and gear-box are either built as one unit or are so closely and so rigidly connected as to make this universal joint between clutch and gear-box unnecessary.

The differential gear, to which reference has already been made, is situated in the centre of the back axle itself. Its purpose is to permit the road wheels to rotate at different speeds when the car is steering round a corner. Its importance and usefulness are not limited to the occasions when the car is literally turning a corner, for when even the car is steered to the right or left in order to avoid other vehicles it virtually turns a corner and the differential gear comes into operation accordingly.

By its action, the differential gear allows both wheels to *roll* along the ground under all conditions. If it were absent, one wheel would have to slip whenever the car turned a corner, for on any other but a truly straight path the outer wheel has the



A Typical Four-cylinder Engine, as exemplified in the design of a small Austin Car

On the left, the carburettor and the magneto are seen in place. On the right, the gear-wheels for driving the cam-shafts, the magneto and the water pump are illustrated, the cover plate having been removed to expose them.

THE TRANSMISSION MECHANISM OF A METALLURGIQUE CHASSIS

The photograph on the left shows the clutch, gear-box, foot-brake, and universal joint at the upper end of the propeller-shaft. The photograph on the right shows the foot-brake, the propeller-shaft casing, the rear axle, and one of the side brakes. The propeller-shaft itself is enclosed in a casing.

greater distance to travel in the same time and, consequently, must either roll or slide over the ground at a greater rate.

Of the two motions, it needs no explanation to show why the former is the more economical in tyre wear and, therefore, more advantageous to the car owner.

Each of the rear road wheels of a live-axle car is driven by a shaft contained within the stationary axle casing. As a rule, the wheels themselves are supported by ball bearings upon the axle casing and are merely driven by the revolving shafts through the agency of suitable couplings in the road-wheel hubs. This arrangement relieves the shafts of the bending stress due to the weight of the car—a weight which, in most cases, the axle casing can more readily be designed to withstand.

At their inner ends, the axle-shafts engage with the differential gear, which will be described in detail elsewhere.

When the road wheels of a car are rotated by the transmission, they tend to move forwards on their own and means must be provided whereby they can push the car. The member forming the connection for this purpose between the axle and the frame is known as a radius rod.

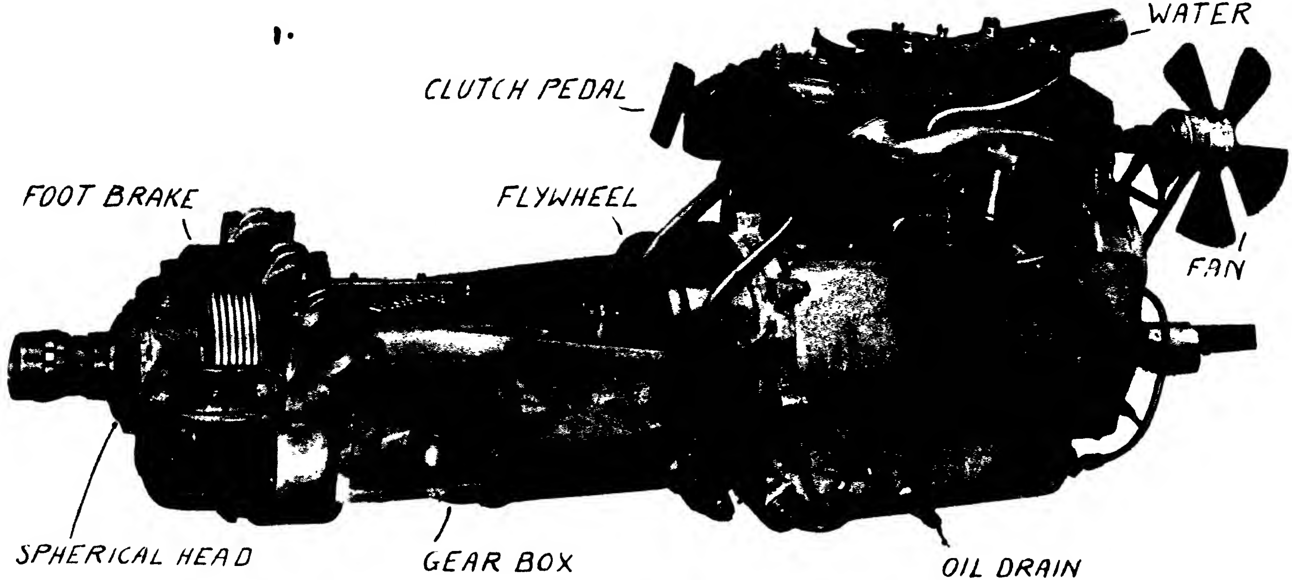
In some cases the springs themselves are hinged to the frame so that they can act as radius rods, but many designers prefer to fit separate radius

rods and to attach the springs to the frame by shackle links in order to give them the necessary freedom of movement. When separate radius rods are used, they are generally fitted under the side members of the frame and are attached to lugs near the extremities of the axle-casing.

In some cases, the radius rod is formed by a casing surrounding the propeller-shaft. This casing is then supported at its upper end in a large spherical trunnion. Such a structure may be used alone or it may be reinforced by radius rods that are intended to receive the direct shock that comes upon one end of the axle when one wheel only strikes an obstacle.

Another member of the chassis that is analogous to the radius rod is the torque rod. When the propeller-shaft drives the axle there is a reaction that tends to make the axle-casing rotate *backwards*. In order to resist this reactionary torque or twist, an independent rod is usually attached to the centre of the axle-casing and is anchored to some convenient transverse member of the frame. Often, the anchorage of the torque rod incorporates a spring buffer in order to allow the transmission to "give" a little if the clutch is engaged carelessly or the brakes are put hard on suddenly.

Sometimes the springs are employed as torque rods. In other designs, the propeller-shaft is enclosed in a casing that resists the torque, but in some instances the upper end of this casing is



THE UNIT SYSTEM OF CONSTRUCTION

Although, on most cars, the engine is entirely separate from the gear-box, there is a method of building them together on what is known as the "unit system"; and the above illustration of the Crossley design is an example of this principle. The engine crank-chamber is bolted to an aluminium casting that surrounds the fly wheel and the clutch. This casting also forms the gear-box. The entire unit is mounted in the chassis frame by a transverse steel tube, the bracket for which is situated just in front of the foot-brake. The front end of the engine is supported by a bearing carried on a transverse member of the main frame.

itself supported on the propeller-shaft, which throws the reaction on to the upper universal joint. In other cars, the casing is independently supported by the frame, either rigidly or through the intermediary of a spring.

There are, of course, a variety of other details in a modern chassis, but the foregoing is a summary of the essential members. I have reviewed the elementary vehicle as comprising a frame suspended on springs above a couple of wheeled axles that are designed for steering and also to carry brakes. Then I have taken note of the engine as a self-contained prime mover doing the work of the horse, and finally I have discussed the essential features of the mechanism whereby the power of the engine is transmitted to the road wheels and the push of the road wheels is communicated to the frame.

Having thus described the chassis in outline, it may be as well to discuss the elements of driving it on the road, as being a matter of more immediate interest to the prospective motorist than is a detailed knowledge of how the aforementioned parts are either made or assembled.

CHAPTER IV

HOW TO DRIVE A CAR

THE art of driving a car may be considered under two heads. One relates to the sympathetic use of the machinery, the other to the proper use of the road. Of these, excellence in the latter is fundamentally the more important quality in any and every driver, but it is the former that alone has the power to reveal the real joy of motoring to the man at the wheel.

Handled just anyhow, a car is no more than a mere mechanism on wheels: it goes along, and that is all that can be said for it. Driven with appreciation of the latent powers and limitations of machinery, the automobile is truly a living thing; it is sensitive as a thoroughbred to its master's lightest touch.

A really refined car is a perfect delight to drive; the feeling of smooth, silent power, and the sense of complete control that comes from the synchronous action of every mechanical detail, bring to the sensitive driver a satisfaction to be numbered among this world's greatest pleasures.

Of all factors making for refinement in car construction and good driving, fundamentally the

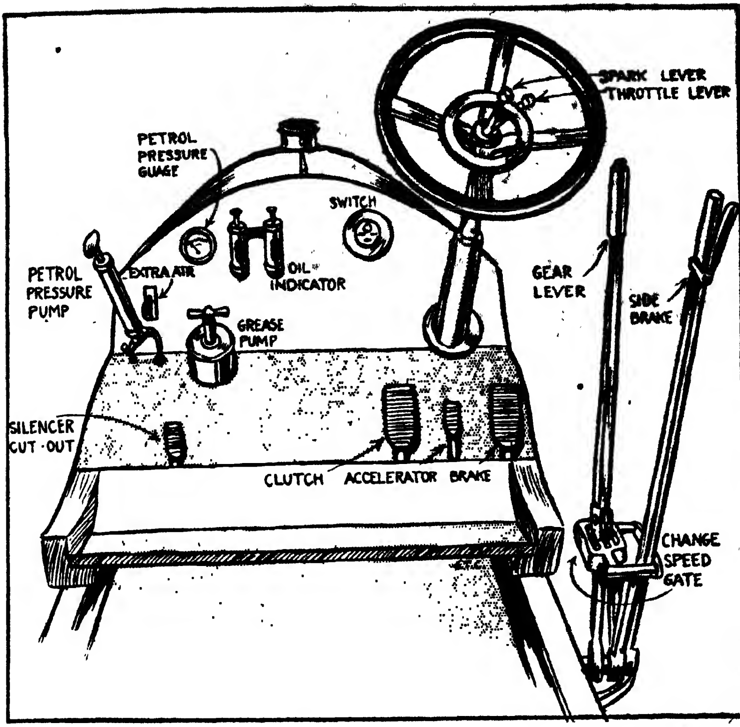
most important, in my opinion, is easy steering. Any car, no matter how heavy, should ordinarily be steerable by the left hand alone. I know of nothing that is so disconcerting and that so spoils good driving, both from the mechanical standpoint and also as regards behaviour on the road, as a stiff or otherwise imperfect steering-gear. Even when the imperfection is so slight as to in no way jeopardize safety, the subconscious effort that is constantly called into play becomes a severe strain on a long journey, and is accountable for much fatigue that otherwise would be absent.

It is fundamentally important, as I have said, that a driver should pay *all* his attention to the road. This is necessary, not only in order that he may be alert against danger, but also in order that he may be alive to the observance of those courtesies that alone enable the driving of any vehicle to be practised as a pleasure. Unless he has a feeling of absolute ease in the control of his car, it is, I contend, impossible for him to be a good driver on the road. If the steering is stiff, he will be awkward and nervous when manœuvring through narrow places, and will especially be guilty of that excessively unpleasant discourtesy of hugging the crown of the road in the face of an approaching car.

To drive on one's own side of the highway is a first principle in the etiquette of the road, and

those who fail to give way from the crown when another vehicle is approaching or overtaking, are guilty of an impoliteness that it is difficult to excuse. Some drivers are obviously nervous about getting too near the kerb or the ditch, but this, I think, shows lack of practice, and the remedy is obvious.

Carters, and drivers of horsed vehicles generally, tend to keep on the crown of a much-cambered road, because it is easier going for the horse, and a certain type of motorist who is prone to imagine that he has a right to sweep the road clear for miles ahead by the abuse of an ear-splitting noise machine, might with advantage bear this fact in mind instead of so impulsively condemning all such slow-moving vehicles to the fires of inferno. If I speak feelingly in this, it is because I think the motor-horn makes an excessively unpleasant noise at its best, and should, therefore, be used sparingly. Because a car is the fastest thing on the road, some drivers imagine that they have a right to push past everything without a second's delay. To be thus " blown at " by some nervous or unreasonably impatient driver is especially exasperating, and causes an irritation of mind that tends to destroy the good-fellowship of the road. Moreover, it is the motorist who has most to gain by increasing the courtesies of the road, for, using the fastest vehicle, he has the greatest need of politeness from others: if only



"Auto" Copyright Sketch.

Sketch illustrating the control members of a car, together with the various dashboard instruments. The subject of the above illustration is a Mercedes chassis, which has an unusually comprehensive group of such fittings. Immediately in front of the driver is the steering wheel, above which are two small levers. One of these is the throttle lever, the other is the spark lever. The throttle lever is set while the car is at rest, so as to enable the engine to run quietly and slowly; it is not moved afterwards. The ignition lever is retarded when running slowly, and particularly when running slowly uphill; it is advanced when the engine is running fast, whether on a high gear or a low gear. The direction in which these levers are moved to effect these objects varies on different cars. The steering wheel is, of course, invariably turned, in order to steer to the right, in the same direction as the natural rotation of the hands of a clock. Near the base of the steering column are the three control pedals. The clutch pedal is invariably the large pedal on the left, and the brake is invariably the large pedal on the right. The accelerator pedal is sometimes between the other pedals and sometimes on the right of the brake pedal. It is always a smaller pedal than the others. The clutch pedal disconnects the engine from the transmission and allows the car to come to rest while the engine is running. The accelerator pedal opens the throttle when it is pressed downwards. When released, the accelerator pedal closes the throttle as much as is permitted by the setting of the throttle lever above the steering wheel. The speed of the car is entirely regulated by the accelerator pedal, which is controlled by the right foot. The ignition lever is

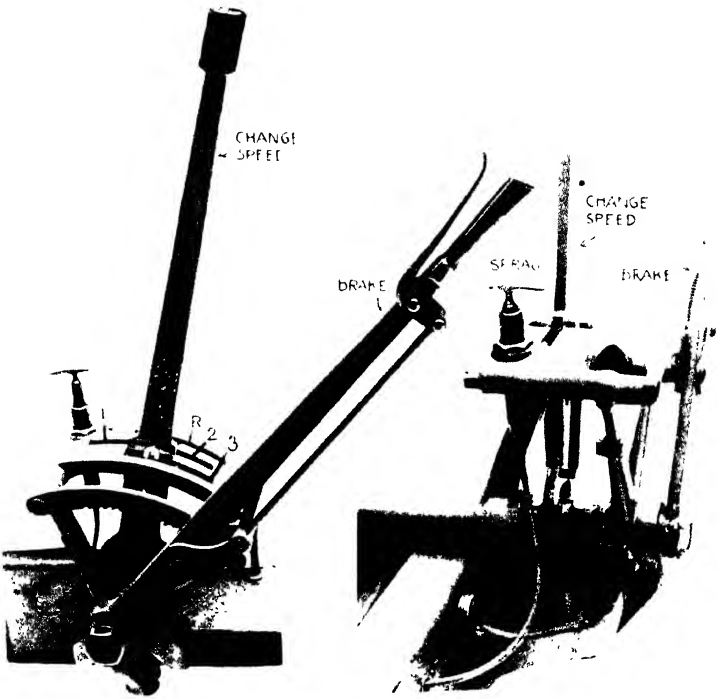
On some cars there are four speeds and on others three speeds, in addition to the reverse. The clutch must be disengaged when changing speed. The side brake differs from the foot brake in having a ratchet attachment so that it can be left "on." Novices commonly forget to release the side brake when starting the car. On the dashboard is a switch which is moved to the "off" position for stopping the engine. The oil indicator must be observed at frequent intervals as an assurance that the oil pump is working. The petrol pressure gauge indicates whether there is sufficient air pressure in the petrol tank for the purpose of forcing petrol to the carburettor. While the engine is running, this pressure is maintained by the automatic action of a pump or by the by-passing of a portion of the exhaust gas. Initially, pressure is obtained by the use of the hand pump on the dashboard. This pump can also be used in emergency while running if there is a leak in the pressure system and the carburettor shows signs of being starved when ascending hills. An adjustment for admitting extra air to the carburettor when travelling at high speed is sometimes fitted. The grease pump on the Mercedes chassis is not usually to be found on other cars, nor is the pedal for cutting out the silencer so as to render the exhaust audible.

for this reason, therefore, he should learn to be polite himself.

I venture to say learn, because the conditions of the road necessarily seem strange to the novice whose first experience of vehicular traffic is obtained from the driver's seat of a car, and much that appears to be impoliteness is engendered through nervous ignorance. At first this is excusable enough, but there are those on the road who seem to imagine that they bought their full competence to drive when they paid their 5 shillings for a driving licence, for they appear to remain quite indifferent to their own clumsiness. Nervousness is at the bottom of most indifferent driving, as can readily be seen by the way in which so many drivers continuously blow the horn whenever they are within sight of another moving object. It is a most objectionable habit, for while it contributes immeasurably to the noise of our streets and to the irritation of people generally, it serves not one whit to enhance the safety of anyone concerned. In short, it is merely an audible advertisement of the driver's own incompetence to control his car properly.

A great deal of the horn-blowing that is at present necessary to safety might be eliminated by the adoption of the principle of "the right of way on one of two roads at a crossing."

If, at a crossing, the traffic on one street were arbitrarily given a right of way, and the traffic on the



Change-speed and Brake Levers as fitted to the larger Napier Cars

The reverse speed is guarded against accidental engagement by a catch on the quadrant. In order to pass over this catch when intentionally engaging the reverse, the handle of the change-speed lever is raised. The sprag is a pawl that engages with ratchet teeth on the periphery of the foot-brake drum. Normally, the sprag is entirely out of action, but when put into engagement by the use of the handle, it prevents the car from running backwards while permitting it to move forwards The sprag on a car is more often an independent fitting formed by a rod with a pointed extremity, which can be lowered into direct contact with the road. In such cases the sprag is controlled by a cable terminating in a ring that is usually hung on a hook below the driver's seat. Sprags are not now invariably fitted to all cars. When the sprag is in action it is desirable that there should be some device positively preventing the engagement of the reverse.

other street made to go dead slow by a sign that must be obeyed, the gravest of road dangers would be abolished, congestion would be alleviated, and the noisy use of the horn would appreciably be reduced.

On points affecting sheer danger on the open road, it is necessary to say less, because caution is an inherent quality, whether possessed in greater or lesser degree. In principle, one should drive always so as to be able to pull up within the length of clear road in sight, but in practice it is scarcely feasible to adhere to the letter of this rule. The saving factor in a tight corner is the continued movement of the other vehicle, which renders it seldom necessary to stop dead. The novice should, however, practise pulling up to a standstill, in order that he may realize just what it means.

When stopping a car in a hurry, it is important not to lock the wheels, because if they once commence to slide, the car is no longer under control, and the retarding force is probably less than the maximum obtainable.

Different sorts of brakes produce different apparent effects, and the driver must learn to use those on his own car to the best advantage. Generally, the foot-brake acts on the propeller-shaft, and usually it has metal-to-metal friction surfaces. Owing to the virtual leverage obtained from the gear ratio of the final drive in the back axle, as well as to the direct mechanical advantage

of its connection with the pedal, such a brake is very powerful, and ordinarily should require no more than the gentlest touch with the toe to bring the car under control. If such a brake is clumsily applied by the full weight of the foot, it will give the impression that the car is about to double up on itself, for the initial retardation of the car tends to throw more of the driver's weight against the pedal, which produces progressively rapid deceleration and consequent discomfort to the occupants. On the other hand, fabric-lined brakes, and especially those that act direct on the road wheels, have the quality of softness in their action, but more force is usually necessary to produce an equivalent effect. For this reason they are less easily abused by the clumsy driver.

On most cars, the side-brake acts on the rear wheels, and, owing to peculiarities in the application of a side-brake, it is on the whole desirable that this brake should not be too sudden in its action. The side-brake is sometimes said to be the emergency-brake, but this is a misnomer, for in emergency a man does what he is most in the habit of doing on ordinary occasions. Most drivers habitually use the foot-brake (which is why, from the engineer's standpoint, there is much to be said for the connection of this brake direct to the rear wheels, in order to reduce wear and tear on the transmission joints), and it is the foot-brake that they will use in emergency.

When driving down long hills it is advisable to use the foot-brake and the side-brake alternately, in order to give the drums and shoes time to cool; and it is because this cooling may be diminished when both hand- and foot-brakes act direct on the rear wheels that some designers object to the practice of so arranging them, apart from the exertion of extra unsprung weight on the axle.

When approaching what may be a steep descent, it is important to slow down before passing on to the slope. On a very steep slope, the pressure of the tyres on the road is diminished, consequently they will more readily slip if the wheels are locked. Also, the road surface is an uncertain quantity; if it should be greasy on a steep descent, the danger of driving fast is very real. There is no excuse whatever for an accident due to neglect of this precaution, and the driver who is caught by his lack of caution is little likely to receive outside sympathy.

Some drivers appear to experience difficulty in releasing the side-brake. It is a perfectly simple operation if initially the lever be pulled slightly *further on* before attempting to release the catch. For this and the other reasons mentioned, it is good practice for a driver to accustom himself to use the side-brake in the ordinary course of driving.

When leaving a car standing on a steep hill,

it is inadvisable to trust to the brakes alone. Either the front wheels should be turned into the kerb, or else a brick should be placed behind the rear wheels.

In the long run, good steering is the driver's greatest asset. To be able instantly to judge space and speed to a nicety and to be competent to guide the car exactly on the chosen course is the quality on which, in a real emergency, the driver is most likely to have to depend. An easy-steering car is essential to the realization of these qualities in practice.

On a straight road, a well-designed car almost steers itself. In any case, the hand really only keeps a check on the general direction. Those who are learning to drive always find it difficult to "give the car its head." They try to steer every yard of the road, and by resisting every slight natural movement of the steering-wheel they wobble erratically from one side to the other.

In steering, one looks ahead, and the faster the speed, the further off is the focus. In thus looking ahead, one takes into one's range of vision all that is happening on either side, but it is always towards the distant focus that one steers the car.

There is a tendency among drivers of a certain class to lounge at the wheel; but I have known no really good driver who did not sit well up to his work. There is a difference between sitting up and being nervously stiff in the seat. It is

impossible to drive properly unless one is comfortable, and when one is comfortable there is no need to be rigidly at attention. Such a position is a sign of undue nervous stress, and must be very fatiguing as well as very unpleasant to the driver. Certainly, it leaves a very undesirable impression on the spectator.

Any car ought to be easily steered over an ordinary road by one hand, and in my opinion the left hand should be used *exclusively* for steering. By this I mean that it should not be required to perform any other necessary duties in the control of the car, for only on this basis is it reasonable to assume that it will confine itself in emergency to its proper duty. It is immaterial if the right hand be used in addition to the left as a matter of convenience, but I contend that a driver so frequently needs his right hand for other purposes that he cannot drive properly unless he is able to control his steering with one hand alone.

With the right hand, it is necessary to do many things that cannot possibly be done if the right hand is always needed to assist the left in steering. By no means the least important of the things that the right hand should do, is to signal the driver's intentions to those whom they concern on the road. Many mishaps, and still more narrow escapes from mishaps, are due to sudden and unexpected movements by drivers who do not

habitually practise the courtesy of signalling their intentions in advance.

There is, perhaps, some difference of opinion as to how best to give warning of specific intentions, but everyone is agreed that some warning is necessary. Personally, I find that many drivers and particularly taxicab drivers, just make one vague signal for each and every different action, and in consequence the only safe course to pursue is one of immediate caution and preparedness for any emergency. It is, however, without doubt, good practice to differentiate between signals, and my own habit in this matter is to point directly to the right when I am about to turn to the right; to move the hand in a circle, like a wheel revolving backwards, when I am about to turn to the left, or to pull up by the roadside. This latter signal is to indicate that following cars may pass by on that side. When just about to stop dead, I hold my hand up rigidly vertical, with the forearm well outside the car, so as to be visible from behind. When driving in a stream of traffic that fluctuates in its speed, it is useful to signal a slowing down as distinct from an actual stoppage, by moving the hand gently up and down, and it must be remembered that all these signals are thoroughly worth while, because there is always the likelihood that the car behind may run into you and do your own coachwork more damage than you would do on your own account by

running into the car in front. As in everything else, however, it is only by making a habit of the practice that a driver can rely upon himself to be regularly courteous in this matter on the road, and under present circumstances it certainly behoves everyone following another car to be prepared for emergency without any such warning.

Following a car always involves a certain element of risk, particularly when the car ahead is acting as pilot across strange country. The need for keeping it in sight is always at conflict with the desirability of keeping sufficiently far behind to be clear of its dust and to be out of danger of running into it should it stop suddenly. When passing through towns, and traffic generally, the driver of the car behind is very apt to get himself into difficulties if he allows his anxiety to keep level to get the better of his judgment. The leading car will often take advantage of a gap in the traffic that it would be dangerous for the following car to attempt, and yet the natural tendency of the driver of the car behind is to follow just where the other car has gone.

Reverting once more to the use of the right hand in driving, its most important purpose is to blow the horn, and although many drivers blow the horn unnecessarily often, it is absolutely essential to blow it sometimes, and the right hand must be ready at the psychological moment. It is because the right hand is needed for this

purpose in particular that I have always been so strongly in favour of the accelerator-pedal as a means of controlling the throttle on a car. In the earlier days, it was common practice to control the throttle, which regulates the power of the engine and, therefore, the speed of the car, by a lever fitted above the steering-wheel, and some manufacturers retained this method alone for many years. A throttle-lever is still fitted above the steering-wheel on most cars; but its present object is to set the minimum throttle-opening that will just keep the engine running nicely when the clutch is disengaged.

If the car is wholly controlled by hand through the agency of the throttle-lever, there is sure to arise an occasion when some danger ahead demands that the driver should either close the throttle or blow the horn. If the throttle is under the control of the right hand, he cannot do both simultaneously, and he must, therefore, either blow the horn while the car proceeds full speed ahead, or close the throttle first and blow the horn afterwards. In this latter case, if the danger does immediately remove itself when the horn is blown, he will tend to feel annoyed at having slowed down the car unnecessarily, and the next time he may try the alternative procedure—with equally unpleasant results.

To argue that the throttle may be controlled by the left hand is to permit interference with the

exclusive use of the left hand for steering purposes. On a question of principle, I find myself unfavourable to such an arrangement, and for the same reason I dislike the idea of fitting the buttons of electric horns alongside the left hand on the steering-wheel. It is true that, in certain positions, they are very convenient when there, but the left hand does not always hold the wheel in the same place or in the same way, and if it tries to keep within reach of the button under all circumstances, it is very likely to steer the car less perfectly than otherwise would be the case.

By the use of an accelerator-pedal, the power of the engine is regulated by a gentle pressure of the foot. When it is necessary to go faster the pedal is depressed, and the foot is raised when it is desired to slow down. In emergency, the foot is removed suddenly and completely from the accelerator-pedal, and the engine slows down to the speed corresponding to the throttle-opening that has previously been adjusted by the setting of the throttle-lever on the steering-wheel.

The actions of the right hand can thus be synchronized with those of the right foot, which controls the accelerator-pedal, and many functions of control depend for their nicety of operation on this sympathetic action. There is not only the previously mentioned case of blowing the horn and controlling the car speed simultaneously, but there is the equally important advantage of being

able to signal to the traffic behind when one is drawing out from a line of vehicles. Also, the operation of changing speed depends for its perfect performance almost entirely on the synchronized control of the throttle and the change-speed lever. If the throttle and the change-speed lever are both controlled by hand, it is obviously impossible to move them simultaneously.

Changing speed is an art that every driver of a car should take pains thoroughly to acquire, for there is nothing that gives such a bad impression, or is so undesirable for mechanical reasons, as the noisy grinding together of the teeth of the gear-wheels.

It is quite unnecessary that there should be any such noise when gear-changing, but I must admit that some cars are much easier to change silently than are others. In order to change speed properly, it is necessary to appreciate the nature of the operation, not only as a mere movement of objects inside a box, but in the light of the mechanical significance of the effect such movement produces.

So far as the former is concerned, the nature of gear-changing consists merely in sliding a toothed pinion out of mesh with one wheel and pushing it into mesh with another wheel. This movement of the sliding members is accomplished by an equally straightforward movement of the change-speed lever. The more important matter

to understand, however, is that when the gears are changed, the ratio of the revolutions of the engine required to produce the former car speed is altered.

Thus, suppose on a certain gear the engine revolves at 1000 revolutions a minute in order to produce 20 miles an hour, and that the gear is then changed "up" to another speed at which 1000 revolutions per minute will produce 30 miles an hour. The car is, let us say, travelling at 20 miles an hour at the moment of gear-changing, and the engine is, therefore, revolving at 1000 revolutions per minute.

If the gear-wheel representing the higher speed of 30 miles an hour at 1000 revolutions were suddenly and in some manner caused to be engaged with its corresponding wheel while the engine was still rotating at 1000 revolutions per minute, the car would tend, in theory, suddenly to shoot forward at 30 miles an hour. In practice, it is impossible thus suddenly to accelerate such a heavy mass as a car, and any serious attempt to do so would result in breakage somewhere.

Actually, it is difficult to cause two gear-wheels to engage when they are rotating at very different speeds, and it is the ill-judged attempt to do so that is responsible for the noise that advertises bad gear-changing to everyone within range.

The process of changing from one speed to another that ultimately will produce a higher car

speed for the same engine revolutions, is called changing "up," and from what has been said above it will be obvious that, in principle, the feature of changing up should be a pause in the movement of the gear-lever between the withdrawal of one gear and the engagement of the next. This pause gives time for the engine-shaft to slow down to a speed corresponding to the car speed and to the new gear ratio.

If the difference in the gear ratio is slight, as often is the case in a gear-box that affords four forward speeds and a reverse, the pause required is less than in the case of a three-speed gear-box, where the difference in gear ratio is inevitably large between one speed and the next.

Also, if the clutch has very light revolving parts, their momentum is small, and they will come to rest more readily than when the clutch is heavy, which will further tend to reduce the duration of the pause in changing up.

Finally, there is, on most cars, a small fitting called a clutch-stop, which is mounted on the clutch-operating mechanism, and is so arranged that it acts as a brake upon the revolving clutch member, thus bringing it more quickly to rest. The pressure with which this clutch-stop acts upon the clutch, depends upon the distance to which the clutch-pedal is moved when the clutch is disengaged, and so the effect of the clutch-stop is directly under the control of the driver. If

the clutch-stop is well designed and properly used it is possible to abolish the pause in changing up altogether. Indeed, I have driven cars in which the change up could be effected as quickly as the hand could move the lever from one end of its quadrant to the other.

The clutch-stop is for use only when changing up, and if it is forced on too hard it will bring the clutch-shaft completely to rest and make the operation of gear-changing more difficult than ever. If this happens, the only way to get the gears engaged silently without stopping the car is to re-engage the clutch and slightly accelerate the engine while the lever is in the neutral position, i.e. between gears.

Most difficulty in changing up quickly comes through lack of judgment in choosing the precise moment for the operation. It is difficult to give general advice on this point, but I have sometimes summed up the situation by saying, "Always change up on a rising note." When driving on a low gear there is, unfortunately, usually a noise in the gear-box, and as the car accelerates this tends to rise in pitch. It is at this moment that it is easiest to change up quickly and silently: if a later moment be chosen, when the gear-box noise has settled down to a steady shriek, a pause in the operation is essential, and any attempt at a quick change is certain to result in the grinding and gnashing of teeth.

It will be found, in practice, that the above rule leads to the change up being effected just as one reaches the crest of a hill. On the level, it implies a very brief use of the lower gears when starting a car. Also, if for any reason the car has been driven on a low gear for some distance at a steady speed on the level, the above advice advocates accelerating *before* changing up, no matter what the speed of the car may be at the moment.

When changing up while going downhill, it is generally necessary to move the lever as quickly as possible, because the car is moving disproportionately fast compared to the engine revolutions. Some drivers put the gear-lever in neutral when coasting, and sometimes find it difficult to re-engage the gears without first stopping the car. In such cases it is necessary to accelerate the engine with the clutch engaged and the gear-lever in neutral, then disengage the clutch and quietly engage the gear.

The amount of such acceleration that is required can only be judged from experience: often I have found it easier to engage the lower gear under such circumstances, owing to over-acceleration of the clutch-shaft.

In all gear-changing operations it is essential to be calm and precise. If the gears grind, on no account force the lever. If in doubt as to whether the relative speed of the clutch-shaft is too high or too low, re-engage the clutch with the lever in

neutral, accelerate the engine, disengage the clutch, and then move the lever into the *lower* speed notch. It is, I have found, often easier to engage the lower speed noiselessly in this way than to engage the top speed in silence.

To change up in a hurry on a hill is sometimes essential, and it is a very exceptional car and driver that effects such a manœuvre silently.

On some cars that have a jaw clutch coupling for the top speed, I have observed that it facilitates silent changing up if the clutch be re-engaged on an almost *closed* throttle while the lever is passing through its neutral position between gears.

In every gear-changing operation it should be an invariable practice to disengage the clutch before engaging a gear. It is possible to disengage a gear without disengaging the clutch merely by suddenly closing the throttle and pulling the gear-lever, but the method is not to be generally recommended. The sudden closing of the throttle causes the car momentarily to overrun the engine, which relieves the pressure on the teeth of the gear-wheels and so permits of their disengagement. Similarly, the next speed can be engaged by an immediate continuation of the movement, but this sort of trick changing should certainly be avoided by the novice.

When changing "down" the conditions to be fulfilled are the reverse of those that obtain when changing "up." After the change, the engine

will have to revolve faster in order to maintain the same car speed, consequently it is necessary to accelerate the engine in the interval between gears.

As in the case of changing up, the 4-speed gear-box requires less acceleration in the interval than a 3-speed gear-box, and some 4-speed cars can be changed up or down as if there were no gears at all in the box.

The action of accelerating the engine while the lever is passing through neutral, is called "double clutching." It may be performed in two ways. One way to "double clutch" is to make the clutch slip by a slight pressure on the pedal and to pull the lever quickly into the lower gear with the throttle full open. This is a slurred movement that is not always as effective as it is intended it should be, but it is the quickest way of changing down in emergency.

The other way of double clutching is to disengage the clutch completely while disengaging the higher gear, and to re-engage the clutch completely when the gear-lever is in neutral. When the clutch is thus re-engaged, the engine is accelerated just as if it were really driving the car, the clutch is then disengaged and the lever moved quietly into the lower speed.

This method involves a series of deliberate actions, and virtually regards the neutral position of the lever as an intermediate speed that

must be engaged in every operation of changing down. With practice, the time lost is very short, and in ordinary touring the delay is of less consequence than it is in a competitive hill climb. Personally, I prefer this method, because it is better suited to the requirements of driving many very different cars. On long hills, I make a practice of changing down very leisurely before the engine begins to labour, and as the car speed is still fairly high under such circumstances this involves considerable acceleration of the engine while the lever is in neutral.

Although the acceleration in neutral is a little alarming to the novice, who generally dislikes the idea of moving his gears while they are spinning fast, it is, nevertheless, the only way to acquire complete control over the silent movement. A good way to practise double clutching is to do the operation on the level, or even on a slight decline along which the car will roll of its own accord, at about 15 miles an hour. All the operations of gear-changing can be studied and practised at leisure in this way.

It will be understood that the right foot is raised from the accelerator-pedal whenever the left foot is disengaging the clutch. This is in order to avoid "racing" the engine when it is suddenly disconnected from the transmission.

When re-engaging the clutch, the accelerator-pedal must be depressed so as gradually to open

the throttle. Success in this combined action is indicated when the engine neither races nor falters in its immediate action. If the throttle is opened too soon the engine will race: if too late the engine will falter, and may even stop.

Practice is required to make the right and left feet work sympathetically on the accelerator and clutch pedals, but their action in this manner is one of the secrets of good driving. Some drivers appear to pay very little attention to the speed of the car when they are re-engaging the clutch, and this is an important defect, because it is the cause of that very unpleasant jerk that sometimes accompanies the action of gear-changing. The degree to which the throttle should be opened in synchronism with the engagement of the clutch depends on the car speed itself. If the car is travelling fast, it is essential to accelerate the engine proportionately when re-engaging the clutch, otherwise the engine will act as a brake. On the other hand, over-acceleration of the engine when re-engaging the clutch causes the car to make an equally unpleasant "leap" forwards.

The intentional use of the engine as a brake on long descents is permissible, but not necessarily desirable. It is effected by merely closing the throttle, and if the braking effect required from the engine in this way is considerable, it is necessary to engage a lower gear.

On excessively steep descents, it is a wise pre-

caution to engage a low speed and to switch off. The engine when thus employed is not a true air brake, because most of the work done by compressing the air in the cylinder during one stroke is given out again by natural expansion during the next stroke. There is, however, some loss of efficiency in this "cycle" of operations which, together with the friction of the engine, constitutes the braking resistance. Some engines have been designed so that, by a movement of the camshaft, they can be converted into true air brakes, but this system has not been widely adopted. It involves operating the valves so that the air in the cylinders shall be discharged after compression.

One objection to the habitual use of the engine as a brake is that its action in this capacity sometimes tends to draw too much oil up past the pistons and on to the cylinder heads, where it may foul the ignition-plugs and the valves. Surplus oil is particularly likely to incapacitate the reserve set of ignition-plugs, if such are fitted, from further action.

On balance, I think it is quite desirable to be able to use the engine as the additional brake when there is any doubt about a very steep hill, and for this reason I am unfavourably disposed toward the permanent interconnection of the clutch with the side-brake, which at one time was common practice in motor-car design. If the clutch is so interconnected that the application of the side-

brake automatically disengages it, there will be no possibility of using the engine as an additional brake simultaneously with the side-brake itself. On a long, steep hill it is desirable to be able to employ simultaneously all the alternative brakes that are available, notwithstanding that, in the ordinary course of events, one would only use them alternately. It has never been quite clear to me that there is any positive advantage in connecting the side-brake with the clutch, beyond the very elementary one concerned with the prevalent habit of novices who frequently forget to release the side-brake when starting the car. This forgetfulness so soon disappears with the advent of a little experience that it is scarcely a factor that should be allowed to have a permanent influence on the detail design of the car.

Any machine is strange and awkward to handle at first, and any driver who desires properly to learn his art is naturally nervous when he first assumes control of the wheel. My own advice to those who would learn to drive a car thoroughly is that they should train their minds first by "looking over the driver's shoulder," so to speak; and I can speak from experience in this, for I learned much from many of the pioneer motorists while travelling as a passenger in the front seat or on the floor, which latter is a fascinating place that motorists nowadays are unable to enjoy on account of the presence of doors to the coach-

work !. Speed changing, the use of the brakes, the judging of distances and speeds, the general behaviour of traffic, and all manner of useful things can be studied in detail and thought out in the mind far better from the passenger's seat than is at first possible under the onus of the responsibility for the actual control of the car. Needless to say, practice alone can bring the knowledge of experience, but as a groundwork the beginner will find such mental instruction extremely useful and very interesting. It is everything in driving a car to do the right thing without stopping to think about it, and this faculty is acquired only when the mind spontaneously dictates the right action as the result of prior knowledge. And, in so far as the training of the mind relates to the mechanical operations of control, much of it may, I think, be acquired in advance by the exercise of a little imagination.

When, having looked over the driver's shoulder long enough to have engendered a strong desire to take the wheel, you find yourself at last sitting in the driver's seat, it is wise to try to bear in mind the fact that you will never be able to drive properly until you feel a thorough composure about all that you undertake.

Be comfortable, and be quiet. Don't fidget, and don't do things by jerks that make your body heave every time you advance the ignition or take out the clutch. Just sit there very peacefully,

yet alert. Let your ambition be so to drive that no one will know when you use any portion of the control. The car must become a part of yourself, and the least thing wrong with it you must detect subconsciously and not by direct attention. Your conscious notice must be devoted to your environment, which also you must try to make part of yourself so far as it is possible to do so. In time you will be able to tell in advance almost exactly what the drivers around and about you are going to do. Or it is perhaps better to say that it was possible to do this at one time, when other drivers kept well to their own side of the road and thought to signal before they changed their course.

Close attention to the traffic is, in any case, of first-class importance, and there is nothing that makes a driver look so *gauche* as to get out of step, so to speak, with the general stream. Such an one nearly runs into the back of the car in front of him and then fumbles with his gears after the policeman has lowered his hand for the traffic to proceed. There he is, still in the middle of the crossing with the vehicles going all ways at once around him, and the inevitable climax arrives when in desperation he puts in the high speed instead of the low, lets his clutch in with a bang and stops his engine.

If this happens to you when you are a novice, as is more than likely to be the case, take your

time about restarting, and don't get flurried by the conversation that springs up in your vicinity. It is always worth listening to, for much of it is highly amusing though a trifle personal and occasionally pointed. Above all, *never try to start the engine before you have actually seen and felt that your gear-lever is in neutral.* Neglect of this precaution may result in the car running over you. Also, put on the side-brake before you leave the car, and remember to retard the ignition and set the throttle in its proper place before you wind the handle. If you do all these things calmly and quietly, and succeed in starting the engine on the first turn, the onlookers may think after all that it was the engine's fault. You will have scored a moral victory, and incidentally will have succeeded in restarting in the shortest possible space of time.

Besides, in starting an engine everything depends on the adjustment of the throttle and the setting of the ignition-lever. The ignition-lever, by the way, is the *other* lever above the steering-wheel. As these levers are seldom marked, their initial identification generally involves an examination of the connections. For starting, it is proper to retard the ignition in order to avoid a backfire, which may do damage to your wrist. A backfire is when the explosion takes place in the cylinder too soon, and so causes the engine to start the wrong way round and to carry the

starting-handle with it. When the engine gets going in the proper direction, the starting-handle frees itself automatically.

If the car is fitted with magneto ignition only, as the majority of cars are to-day, it does not facilitate starting to have too much retard. Full advance is sometimes the only way to start easily, but you must hold the starting-handle with due regard to possible emergencies and in such fashion that it can slip through your fingers without much trouble. If the ignition is properly advanced and the carburettor properly set, any good engine ought to restart when warm with a single pull-up of the handle. *Some* magnetos are designed especially to start with a full retard.

Winding or swinging the engine is an occupation of which, at the best, it may be said that "a little goes a long way." There is a knack about swinging an engine that some people find much difficulty in acquiring. It does not need strength, as a rule, for many strong men are absolutely nonplussed by an engine that a child, having the knack, could wind easily.

Having restarted the engine under the trying circumstances represented, for instance, by an accidental stoppage in the middle of Piccadilly Circus, you retake your seat and then experience what is perhaps the most trying moment of all for the novice. All your good resolutions about using the clutch and the accelerator in harmony

are very apt to go to the winds. Also, there is that inevitable trick of leaving the side-brake on, so that even an otherwise well-executed start is rendered abortive in the most ignominious manner, and the whole process of restarting the engine has to be gone over again.

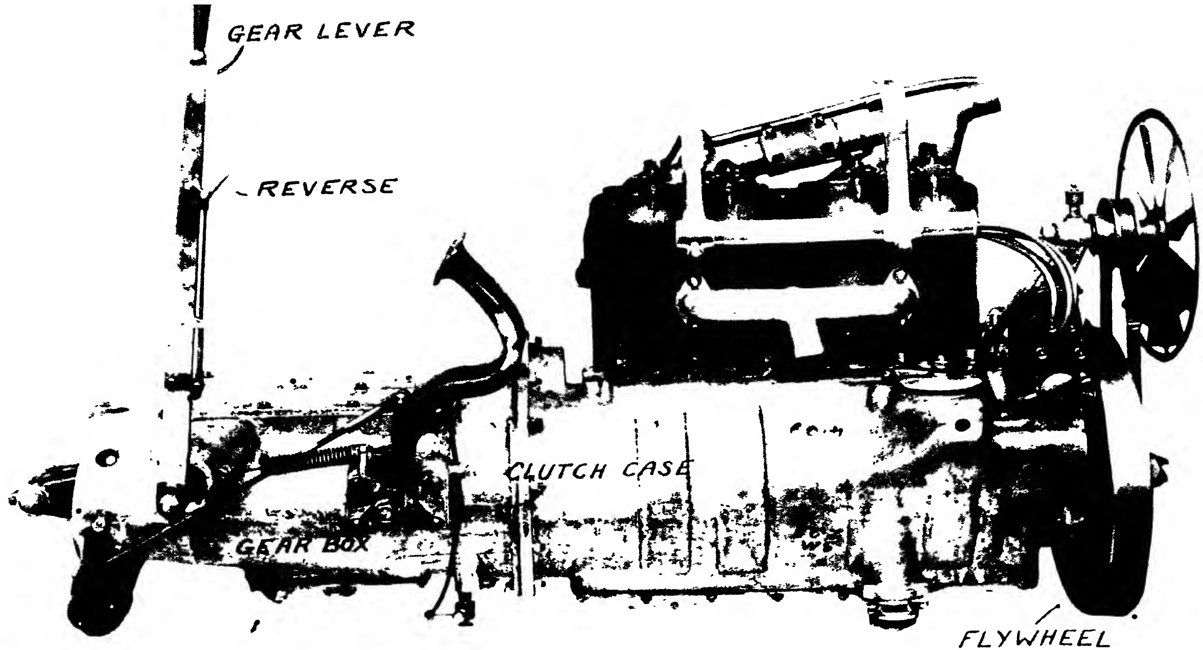
One little fault noticeable in many drivers is that they grind their gears before starting, when first moving the change-speed lever. This is due to not using the clutch-brake sufficiently. The car being at rest, the clutch-shaft must also be brought to rest before the gears can be engaged silently. The engine is probably running rather fast, as it has just been started on a partially open throttle, and so the clutch-shaft will have a good deal of spin on it when the clutch is first disengaged. The remedy is to push the clutch-pedal right forward and to pause a moment before moving the lever, so as to make quite sure that the clutch-shaft is stationary.

Having engaged the low speed, take off the side-brake ; not vice versa. Then let in the clutch gently, and not so as to skid the wheels. In starting a car, as in overcoming other difficulties, there is much truth in the old adage " The more haste the less speed."

Remember also to retard the ignition when you are forcing the car to accelerate or to climb hills on the top gear. Advanced ignition should accompany high engine revolutions or light loads

only; a retarded spark is necessary when the engine is pulling slowly uphill. But it is always advisable to advance the ignition as much as the engine will stand without "knocking," for it promotes economy in petrol consumption and prevents overheating.

When driving keep your eye on the road and be prepared for any emergency. Never look at your control-levers, for you must be able to find them and use them properly while still looking ahead. Never release your left hand from the steering-wheel; but while your grip on the wheel should be secure, keep a supple wrist so that the car may follow its own straight course. It is on your ability to do the right thing with the wheel you will most depend in emergency.



ANOTHER EXAMPLE OF THE UNIT SYSTEM OF CONSTRUCTION

An uncommon feature of this Napier design is the position of the fly-wheel at the front end of the crank-shaft. The clutch is enclosed by an extension of the crank-chamber, which is bolted to a corresponding extension of the gear-box. The unit also carries the change-speed lever. The foot-brake is enclosed in an extension of the gear-box casing, and is, therefore, invisible in the above photograph.

CHAPTER V

DETAILS OF THE TRANSMISSION MECHANISM

AS the general purpose of the chief members of the transmission mechanism of a car has been explained in a preceding chapter relating to the component parts of the chassis, it only remains in this section of the book to describe in greater detail the construction of those members, so that their action may more readily be understood and their proper use better appreciated.

The clutch is the first member of the transmission system, and its purpose is to disconnect the engine from the shafts that drive the road wheels. When the clutch is "in" the engine is coupled up to the transmission so as to drive the car; when the clutch is "out" the engine is disconnected and may run freely without driving the car. Similarly, the car can "coast" downhill when the clutch is "out" without turning the engine.

The clutch is situated immediately behind the engine, and on most cars is just under the dashboard. Usually it is incorporated with the fly-

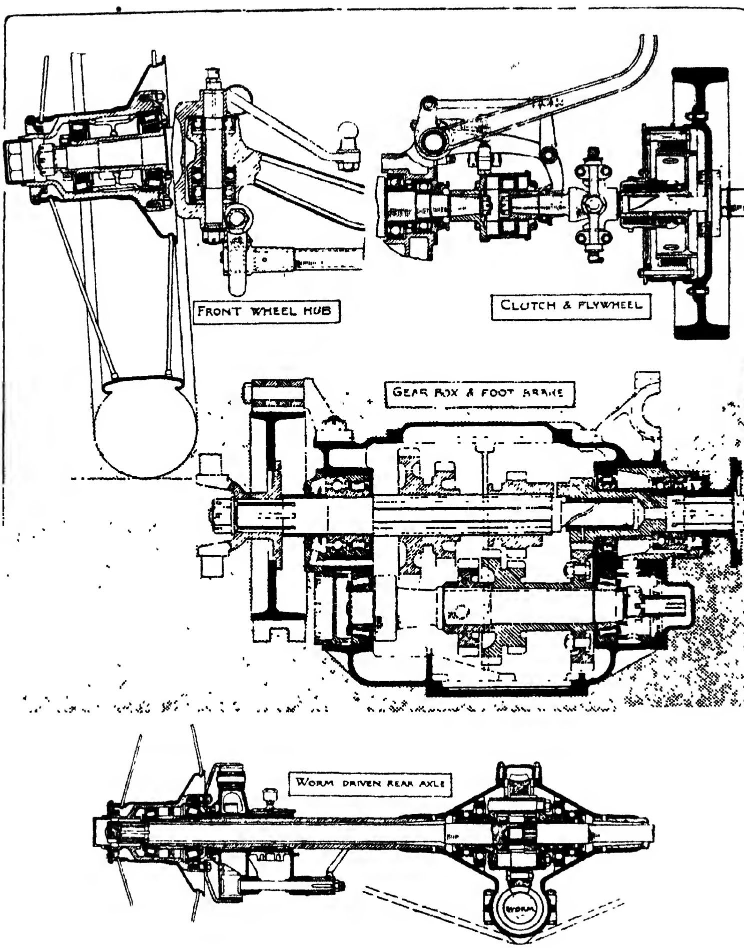
wheel, but occasionally it is to be found in the gear-box.

The simplest form of clutch is the cone type, and the simplest form of cone-clutch is that in which the fly-wheel is hollowed out to receive a shallow aluminium cone that has its tapered rim surfaced with segments of leather. The leather, which is riveted in place, affords a good grip against the metal face of the fly-wheel, and if the leather is kept in good condition by an occasional dressing of suitable oil, the action of a leather cone-clutch will be quite smooth in its engagement.

A strong spring is used to force the cone against the fly-wheel, and this spring may be concentric with the clutch-shaft, or so arranged as to operate through the clutch-pedal mechanism. Sometimes a series of smaller springs situated between the shaft and the rim are used instead of a single spring: it depends upon the detail of the chassis design as to which system is adopted.

An extension of the engine crank-shaft forms a spigot for the support of the movable clutch-cone, and it is important that this bearing should be lubricated. When the clutch is out, considerable relative motion takes place at this point.

In some cone-clutches, the leather surface is abandoned in favour of metal, but usually an all-metal clutch consists of discs. Some clutches of this type have twenty-four discs; half of them are



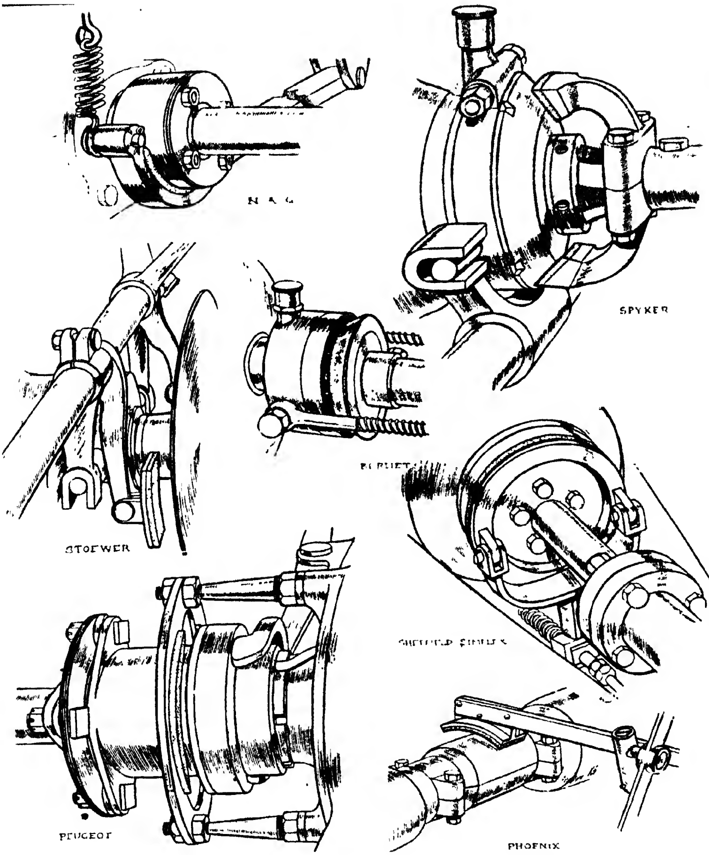
Detail in chassis construction, as exemplified on a Wolseley car.

carried by a casing bolted to the fly-wheel, and the remainder belong to the clutch-shaft. The fly-wheel and clutch-shaft discs are adjacent to each other, the two sets being, as it were, interleaved with each other. When pressed together by the clutch-spring, they virtually form a solid mass, and the fly-wheel is thus coupled up to the transmission. When the spring pressure is released, the plates slip over each other at once, for it is only when they are forced tightly together that these flat surfaces can exercise a grip on one another.

In a disc-clutch, the clutch-pedal does not directly act upon the discs themselves, but only on the clutch-spring. The discs do not move appreciably, for they do not wedge together, as in the case of a cone-clutch. In one type of disc-clutch, however—the Hele-Shaw—the discs are corrugated with a concentric V grooving.

As a rule, the disc-clutch has numerous thin plates, and is lubricated with oil contained in the clutch-casing. Other forms of disc-clutch have fewer and thicker plates, and are often lubricated with graphite. These clutches are frequently referred to as "plate" clutches.

Although many types of change-speed mechanism have been invented, the earliest has survived them all. It consists of two shafts side by side, the one being driven from the other by a pair of gear-wheels. The second shaft, to



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Various forms of clutch-stop. The clutch-stop is used for checking the rotation of the clutch ıen changing up. It is connected to the clutch-pedal and is brought into action by pressing the dal further forward than is absolutely necessary to disengage the clutch. It is used only when anging up, never when changing down.

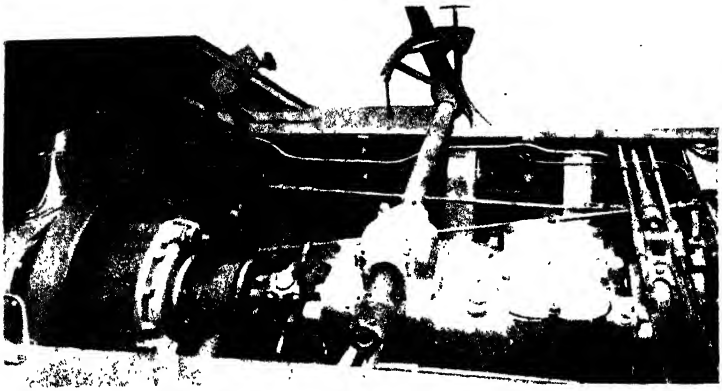
which the power is thus transmitted, is known as the lay-shaft.

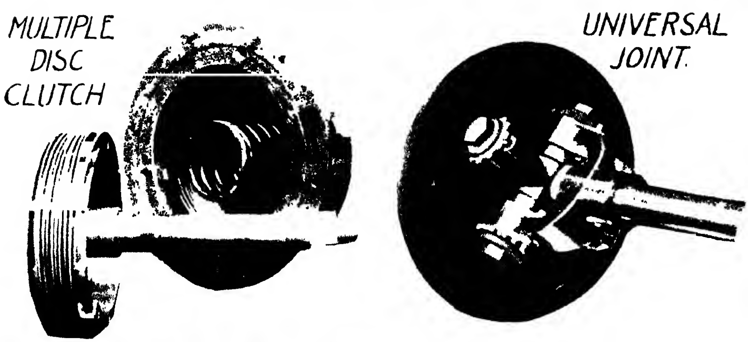
On the lay-shaft is a row of spur-wheels, and nearly opposite to each wheel is a corresponding spur-wheel on a shaft that lies in line with the above-mentioned engine-driven shaft, but is in fact a separate member. This latter shaft is connected to the propeller-shaft, and is frequently called the "through" shaft.

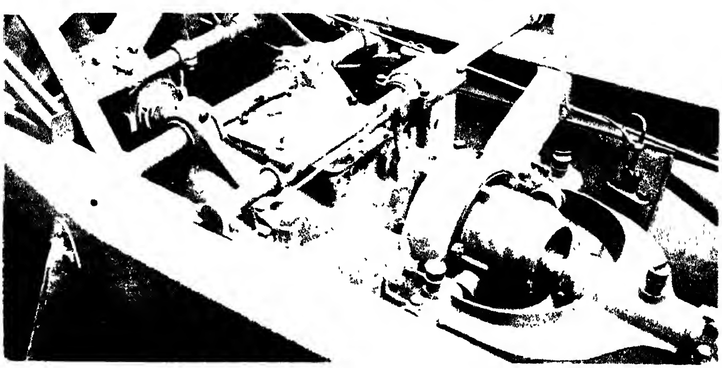
The spur-wheels on the through-shaft are free to slide axially, and their positions are controlled by forks that engage with grooves cut round the bosses of the wheels. Usually, these wheels are joined together in pairs, so that two forks serve to control the movement of four wheels.

The forks themselves are controlled by the change-speed lever. Each fork is connected to its own rod, and the lever engages with one rod or the other according to its position in the change-speed quadrant. It is when the lever is passing through the "gate," or slot, in the middle of the quadrant, that it is disengaging from one rod and engaging with the other.

By moving the change-speed lever forwards or backwards, one of the rods is caused to slide one of the gear-wheels along the through-shaft, so that it engages with one of the gear-wheels on the lay-shaft. The engine-power is then transmitted from the lay-shaft to the through-shaft, and so to the propeller-shaft and to the back axle.







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THE CENTRAL PORTION OF A CHASSIS, SHOWING THE CLUTCH AND THE GEAR-BOX IN SITU

The upper view is taken from a Napier chassis, the lower photograph being a Stoewer. In the centre a multiple disc-clutch from a Vauxhall car is shown dismantled. On the right is a universal joint from a Napier car. The multiple disc-clutch is enclosed in a casing that is bolted to the fly-wheel. One part of the universal joint is carried by the foot-brake drum.

In the meantime, the other operating rod is held firmly in its neutral position by a locking device that is automatically controlled by the movement of the change-speed lever. It is impossible, therefore, for two speeds to be simultaneously engaged.

According to the relative sizes of the engaging wheels so is the gear ratio corresponding to the gear in use. Thus, if the wheel on the lay shaft is small, and that on the through-shaft is large, the gear ratio is low, because the lay-shaft, and therefore the engine, will have to turn many times in order to turn the through-shaft once.

It is modern practice to provide a direct drive on the highest or "top" gear. This is obtained by coupling together the engine-shaft and the through-shaft by a direct connection that dispenses with the intermediate lay-shaft. The connection is effected by some kind of jaw-clutch, which may be formed by sliding one of the gear-wheels inside a hollow member that has gear-teeth projecting inwards.

The purpose of the direct drive is to decrease noise, and increase efficiency. In itself, it is absolutely quiet, and it loses no power, which accounts for the relative silence of a car that is being driven on "top" as compared with its behaviour on one of the low speeds when hill climbing.

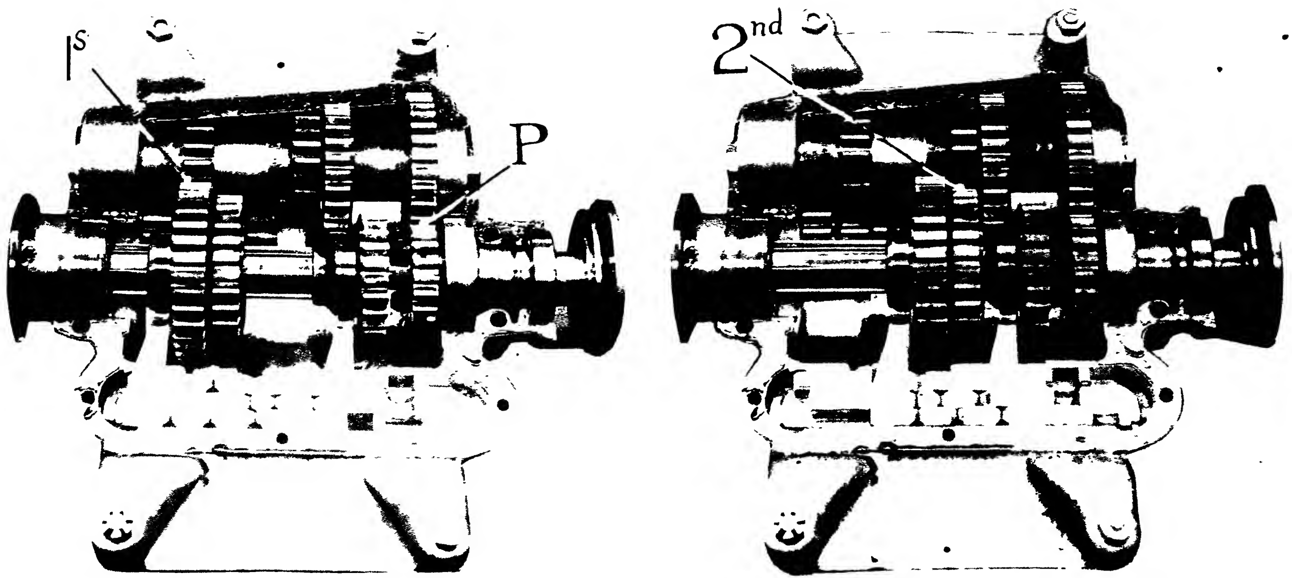
In addition to the forward speeds, the gear-box

must also provide a reverse. This is usually obtained by sliding another pair of gear-wheels simultaneously into engagement with wheels on the lay-shaft and the through-shaft. These reverse pinions are carried on a separate shaft that is commonly situated at the bottom of the gear-box. They are operated by an independent rod, to control which the change-speed lever has to be moved into a notch in the quadrant that should normally be protected by a latch. In gear-boxes that have only three speeds, a modified system of control is employed by which the need for a separate rod is obviated.

Sometimes the through-shaft in the gear-box forms the member that is driven directly by the engine. In this case, the power is transmitted first to the sliding-wheels on the through-shaft, thence to the lay-shaft and from the lay-shaft back again to a short shaft that is connected to the propeller-shaft.

In this type of gear-box the "permanent" mesh-wheels, that is to say those between the lay-shaft and the propeller-shaft, lie at the rear end of the box. In the previously described design, the permanent mesh-wheels, which in this case belong to the engine-shaft and the lay-shaft, are situated at the front end of the box.

The essential difference in the two systems concerns the speed of the lay-shaft when it is revolving idly while the car is on its direct drive.



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THE INTERIOR OF A TYPICAL SLIDING SPUR-WHEEL GEAR-BOX

The view on the left shows the first speed in position. The power is transmitted from the engine through the coupling on the right, and through the gears in permanent mesh marked "P" to the lay-shaft, which carries the pinion engaging with the largest of the sliding spur-wheels on the through-shaft. The pair of wheels in engagement is marked "1st." On the right, the second speed, similarly shown in engagement, is marked "2nd." It will be noticed that the same sliding member as is used for the first speed has been moved along the through-shaft for the engagement of the second speed. A Vauxhall gear-box is the subject of these photographs.

If the permanent mesh-wheels are in front, the lay-shaft revolves at a slower speed than the through-shaft; if they lie behind, the lay-shaft revolves at a higher speed than the through-shaft. The desirability of a slow-speed lay-shaft is due to the fact that it is likely to be less noisy and that it facilitates gear-changing.

In a few cases, means are provided whereby the lay-shaft is disconnected on the direct drive and so can come to rest. Apart from increased cost of construction, this system is apt to need a little more care in changing down from the direct drive to the next lower speed.

Also for the sake of silence, the teeth of the permanent mesh-wheels are sometimes cut on the slant. Such wheels are called "helical wheels," and because the engagement of their teeth during rotation is progressive, they are potentially less noisy than a straight-cut tooth.

In the gear-boxes on the London omnibuses, the lay-shaft and the through-shaft are connected by "silent" chains instead of by direct meshing gear-wheels. These special chains are not roller chains, like those used on bicycles, but are more like a steel belt with inwardly projecting teeth. The teeth engage with gear-wheels that outwardly resemble those ordinarily employed in gear-boxes. The chains do not slide in order to change gear; instead, one of their gear-wheels rides freely on its shaft, and a jaw-clutch is used to couple it

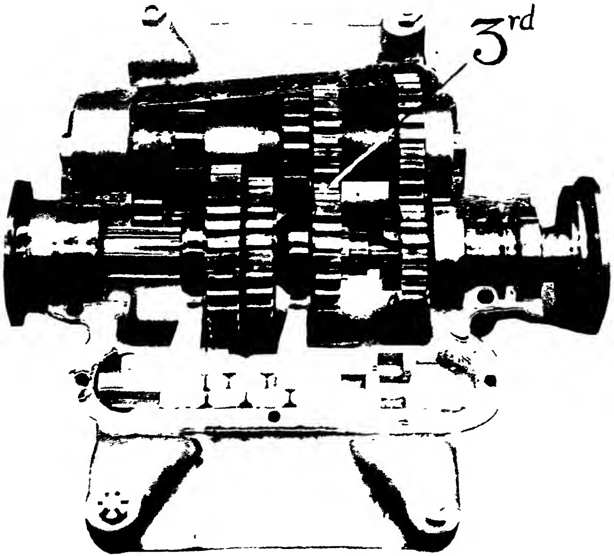
to the shaft when that particular speed is required. There is a chain for each speed, and the jaw-clutches are controlled in the orthodox way by a change-speed lever.

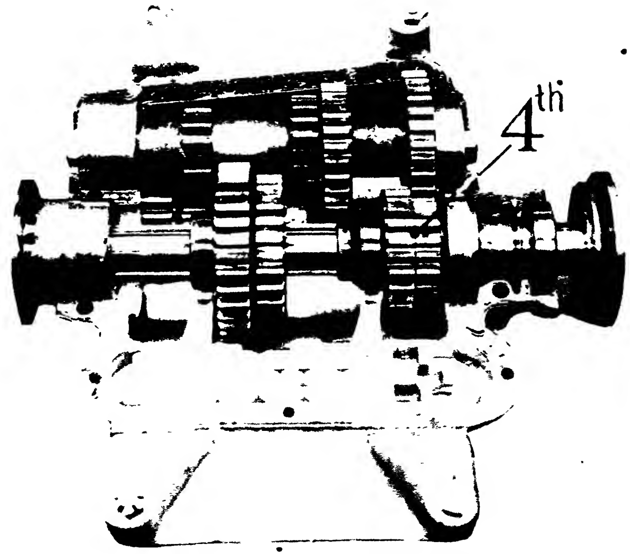
Silent chains of this type are now frequently employed for driving the cam-shafts of engines and for driving the magnetos, but they have not been adopted in the gear-boxes of pleasure cars.

Immediately behind the gear-box is, usually, a brake. This consists of a steel drum, carried on an extension of the gear-shaft, and a pair of shoes, supported on the gear-box itself. These shoes are generally controlled by a pedal, but on a few cars they are operated by the side-lever. They may be either outside the drum, in which case they contract upon its exterior, or enclosed within the drum, in which case they expand against the interior surface of its rim.

The movement of the shoes is slight, and is obtained either by rocking a cam, by turning a screw, or by the direct pressure of a toggle-lever. In most cars the brake-shoes have cast-iron liners riveted to them; the drums are generally made of steel.

Attached to the brake-drum is one half of the universal joint, the other half being fastened to the propeller-shaft. These halves are commonly fork pieces, and they are joined together at right angles by a + piece. In order to provide a limited amount of telescopic motion, the propeller-





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THE THIRD AND FOURTH SPEEDS IN ENGAGEMENT

It will be noticed that the third speed is obtained by moving a different sliding member from that used for the first and second speeds. The first and second speed sliding member lies in its neutral position. The fourth speed, or top gear, is a direct through drive from the engine-shaft to the through-shaft. It is obtained by the engagement of a jaw-clutch, of which one part is formed on the face of the third-speed sliding member. The other part is similarly formed on the face of the permanent mesh pinion driven by the engine-shaft.

shaft is usually arranged to slide inside the boss of its forked extremity, the necessary engagement being maintained by grooves and solid keys, or by a simple squared end on the shaft.

Another form of universal joint consists of a hollow cylindrical member that is rigidly attached to the brake-drum. The other half of the coupling, which is rigidly fixed to the propeller-shaft, is free to slide to and fro inside this box. The connection between the two parts is effected by a pin fitted at right angles to the propeller-shaft. This pin engages with grooves in the outer box, suitable metal blocks being fitted to the extremities of the pins in order to locate wear on readily renewable members.

Yet another form of universal joint consists of several layers of leather riveted together in the form of a ring, which is used to join together the two forked members.

From the universal joint, the power is transmitted to the propeller-shaft, which needs no detail description, and thence to the level pinion that drives the crown-wheel on the live rear axle.

In some cars, the bevel gear is replaced by worm gearing for the sake of greater silence, in which case the worm-wheel occupies a similar relative position to that occupied by the crown bevel wheel.

The bevel crown is bolted to a cage-like box containing the differential gear, the purpose of

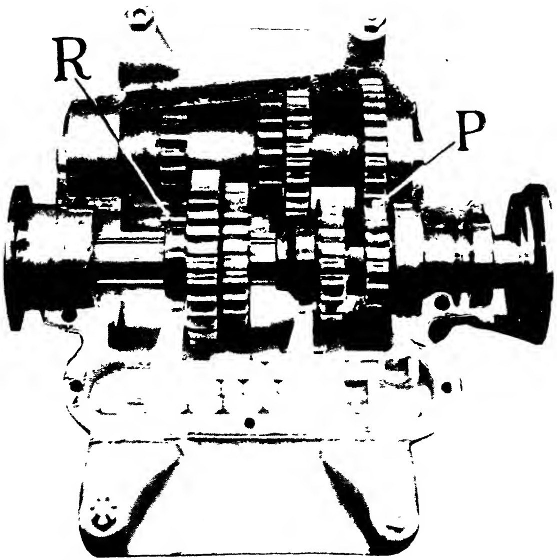
which has been described in another chapter. Inside the differential cage are spur pinions that engage with pinions fastened to the inner ends of the two halves of the live axle proper.

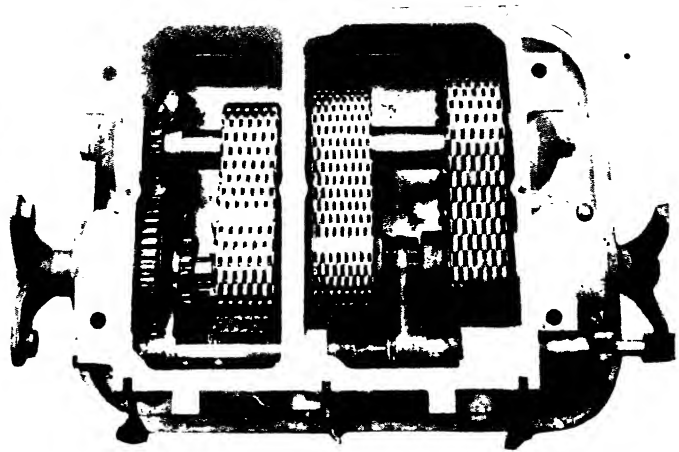
For the purposes of explanation, it will be more convenient to describe the differential gear as if the cage contained only one pair of pinions. These are carried on parallel pins that lie across the cage and are supported in its side walls. When the cage revolves, the pins and the pinions move bodily around the axis of the back axle.

One of the differential pinions engages with the pinion on the inner end of one of the live-axle shafts. The other differential pinion similarly engages with the pinion on the inner end of the other half of the live-axle shaft.

The differential pinions also engage with each other. This is effected by making the differential pinions wider in the tooth than the axle-pinion, so that they can overlap each other. It is, of course, this overlapping portion that is in engagement.

If we imagine the differential cage to be held stationary while one of the halves of the axle is rotated, the differential gear will act as a simple reverse mechanism. Thus, the axle-pinion will drive one of the differential pinions, which will rotate the other differential pinion in the opposite direction. This in turn will drive the other half of the live axle *backwards*.





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THE REVERSE GEAR IN POSITION AND A CHAIN-GEAR BOX •

The reverse speed is obtained by sliding a pair of pinions that are mounted on a spindle in the bottom part of the box. These pinions engage with the first-speed gears on the lay-shaft and the through-shaft, and they reverse the motion that is transmitted from the lay-shaft to the through-shaft via the first-speed wheels. At the same time, they introduce a further gear reduction, so that the reverse is a lower gear than the first speed. On the right, is seen the interior of a chain-gear box such as is used on the Daimler 'buses and other public service vehicles in London. The lay-shaft and the through-shaft carry gear wheels that are connected by belt-like toothed chains. The speeds are engaged by sliding jaw clutches.

If we now imagine that the whole differential gear is revolving bodily on its own axis, while the above-described rotation of the shaft is proceeding, it will be apparent that this superimposed motion of the differential cage will tend to accelerate the forward rotation of one wheel, and decelerate the reverse rotation of the other. Thus, for example, we can imagine one wheel at rest while the other road wheel rotates forward at twice the speed of the forward rotation of the differential cage itself.

Having explained in detail how one wheel may rotate backwards while the other rotates forwards, and how one wheel may be stationary while the other rotates forwards, it needs no further explanation to show that the two wheels may both rotate forwards or both rotate backwards, but at different speeds. In short, it has been explained that the differential gear is, in fact, a mechanism that enables a differential rotation of the road wheels to be realized in practice. Its object, as has been explained before, is to permit of the outer wheel rotating faster than the inner wheel when the car is turning a corner.

Its mechanical significance is that while thus rotating at different speeds, both wheels continue to receive power from the engine. It would be easy to provide the necessary differential freedom of rotation by merely mounting one of the road wheels loose on the axle, but in that case the

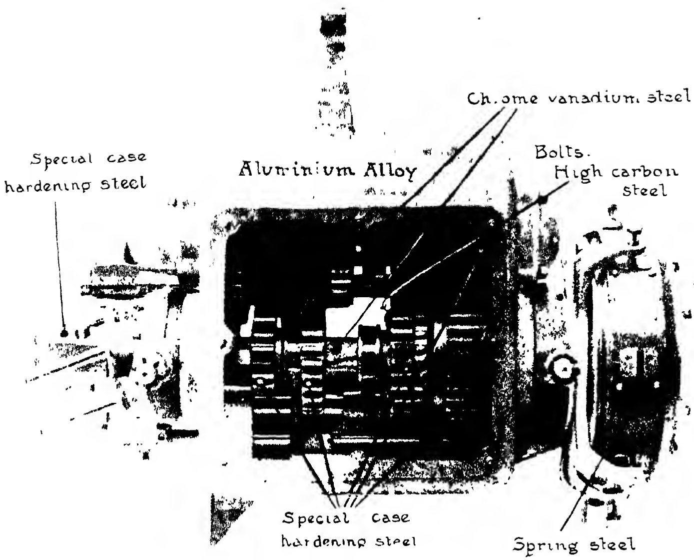
entire driving strain would always come upon the other tyre.

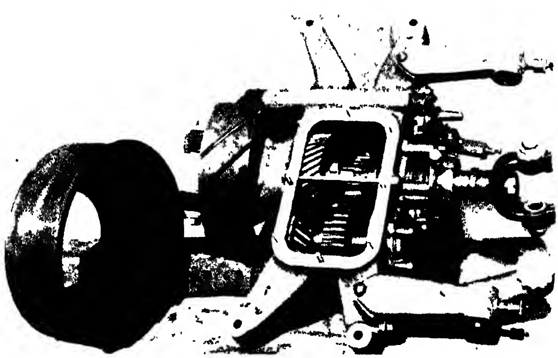
There are two systems of mounting the road wheels on the back axle, one being to fasten them directly to the live-axle shafts, which themselves are supported inside the axle-casing by ball or roller bearings, while the other system is to support the wheels directly upon ball bearings carried by tubular extensions of the axle-casing, which are arranged to project into the hubs of the wheels. In this latter case, the live-axle shafts are fastened to the wheel-hubs by some form of suitable coupling.

It has already been explained that the differential cage is itself rotated by the main system of gearing that is under the direct operation of the propeller-shaft. In some cars this gearing is of the bevel spur pinion type, in others it consists of a worm and wheel.

The worm-driven axle essentially performs the same purpose, and operates in the same way as the bevel-driven axle. The only difference in construction is that the toothed crown-wheel and bevel pinion are replaced by another form of toothed wheel that is designed to engage with a worm.

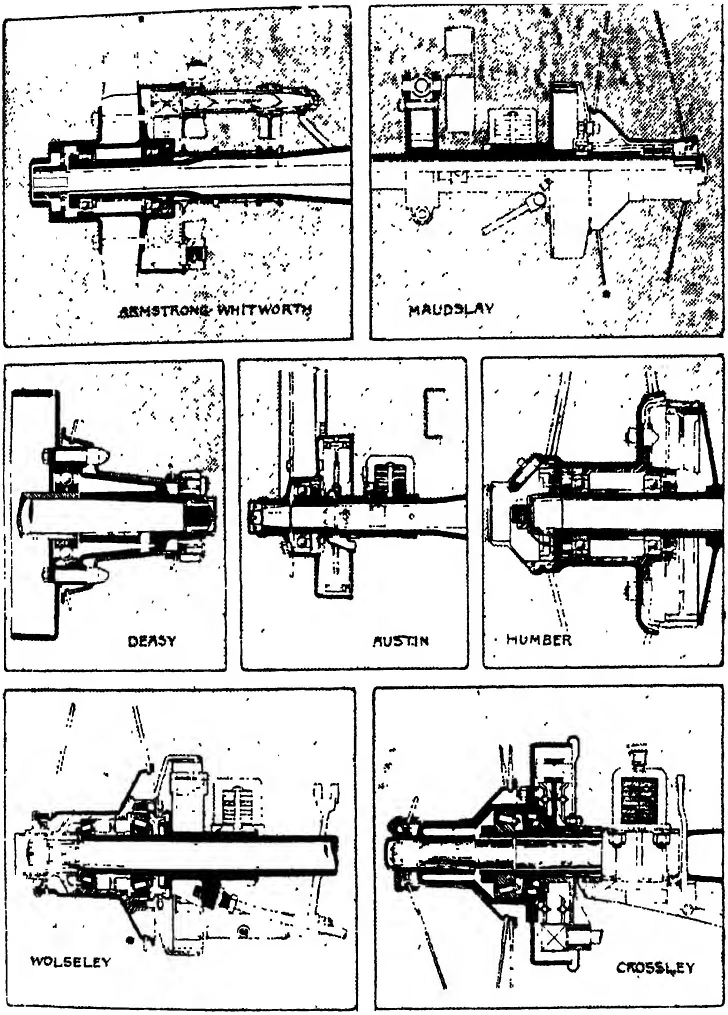
The worm is merely a length of screw thread, such as is cut on any ordinary bolt or wood screw, but it is, of course, of entirely different proportions. The worm-wheel is analogous to the nut





THE UPPER VIEW SHOWS THE INTERIOR OF A DAIMLER GEAR-BOX AND INDICATES SOME OF THE MATERIALS OF ITS CONSTRUCTION

A contracting foot-brake of the band type is also seen in place, while on the left is a portion of the universal joint. Below is an interior of a Napier gear-box, illustrating the use of helical teeth on the permanent mesh gears. It can easily be seen that the teeth of the wheels on the left are cut on the slant.



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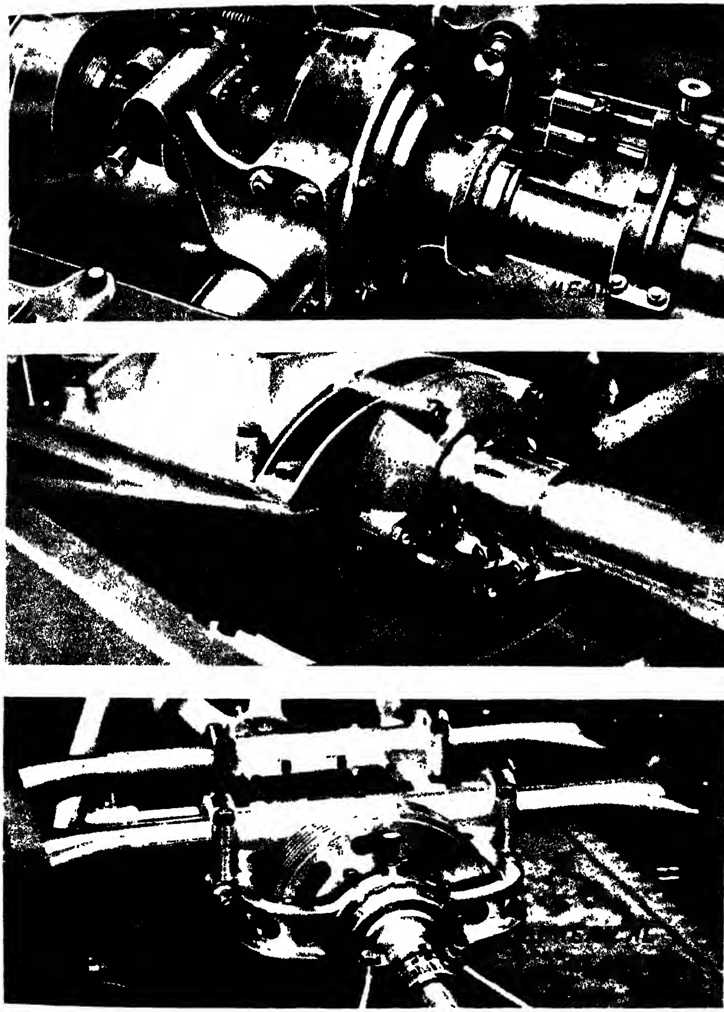
Methods of supporting the road wheels on the axles of different cars. In all the cases illustrated, the weight is supported by a tubular extension of the axle-casing, but it is particularly interesting to observe the variety in the number and disposition of the ball bearings. In the Wolseley and Crossley designs, Timken conical roller bearings are employed instead of ball bearings.

on an ordinary bolt in its method of engagement with the worm, but its construction is also entirely different, for the engagement takes place tangentially on the surface, instead of axially through the centre. When the worm rotates, the worm-wheel turns on its own axis instead of advancing along the worm as would be the case if it were a nut on a screw thread. In some cars, the worm is placed above the worm-wheel, in others it lies beneath. The underneath position reduces the road clearance and increases the obliquity of the propeller-shaft. The overhead position sometimes interferes with the coachwork.

Most manufacturers who have adopted the worm-drive have done so because of its inherent quality of silence. The worm-drive is by nature a more silent mechanism than the toothed bevel, because its method of transmitting power is absolutely continuous, and of a sliding wedge-like kind. The bevel depends for its continuity of action on the accuracy of its manufacture, since by nature its operation consists of a sequence of blows. To some extent, the worm and the bevel may be compared, respectively, to the propeller and paddle-wheel in steamship propulsion.

Theoretically, when one tooth of a spur-wheel mechanism comes into engagement with its mate, there should result a sliding contact of infinite gentleness and precision. It is difficult to reproduce in metal the absolute accuracy so readily



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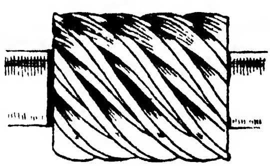
SPHERICALLY-HEADED PROPELLER-SHAFT CASINGS

Three instances in which the propeller-shaft casing is used as a combined radius and torque rod are to be found in the Sheffield Simplex, the Argyll and the Crossley cars illustrated above, in the order mentioned. In each case, the propeller-shaft casing terminates in a spherical head that rests in a corresponding trunnion attached to the frame.

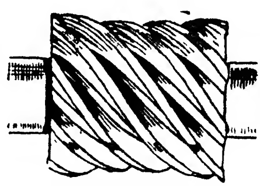
manifested on the draughtsman's drawing-board, and still less easy to maintain such a strict tooth contour throughout a long and active life.

Accuracy is not less desirable in a worm-driven axle than in the bevel, nor is it necessarily obtained with greater ease, but as the worm-drive is by nature more silent, the consequences of deviation from the absolute are less likely to be pronounced.

Two kinds of worm are employed in automobile construction, one being the ordinary straight worm, and the other the concave worm, which in automobile circles is sometimes called the Lan-



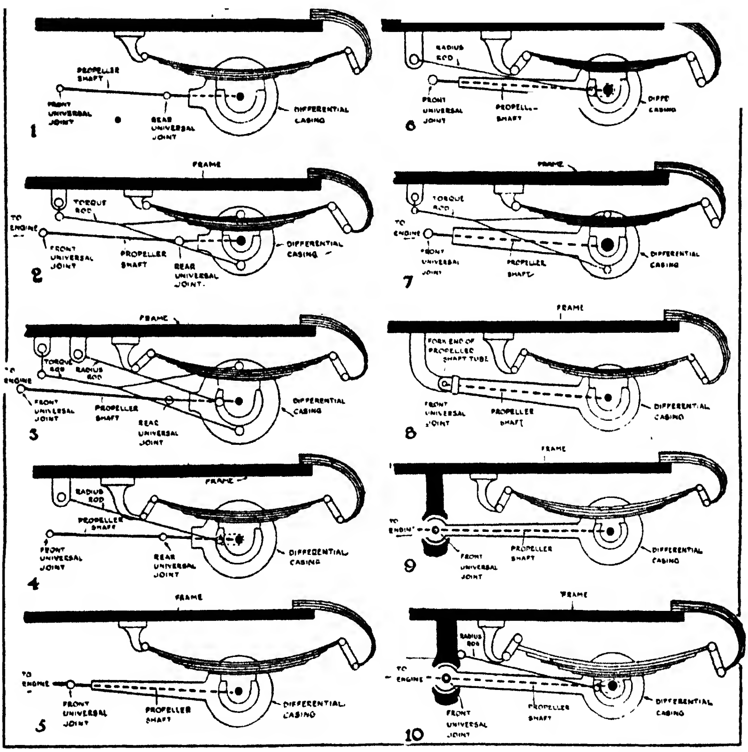
The ordinary worm.



The Lanchester worm.

chester worm. An ordinary worm is a length of thread cut on an ordinary solid cylinder of steel. In the Lanchester worm, the walls of the cylinder on which the thread is cut are concave, being somewhat like an hour-glass. The object of this latter design is to enable the worm to embrace a longer arc of the circumference of the worm-wheel, thus bringing more of the worm into action simultaneously. A worm as used in engineering often has several parallel threads, whereas an ordinary screw commonly has one thread only.

Having delivered the power of the engine to the road wheels, it is necessary to provide means whereby the thrust of the road wheels can suitably be applied to the chassis-frame. Owing to



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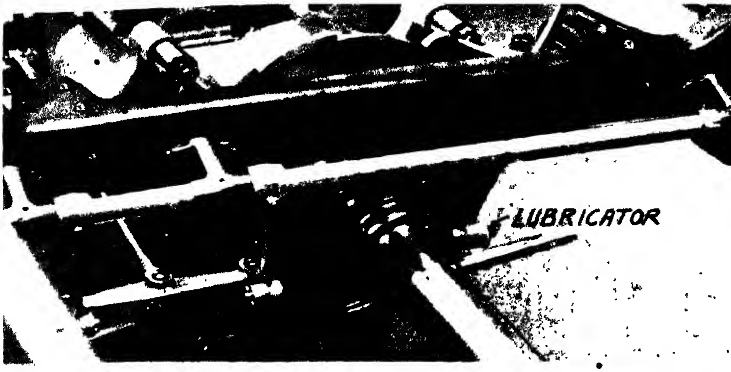
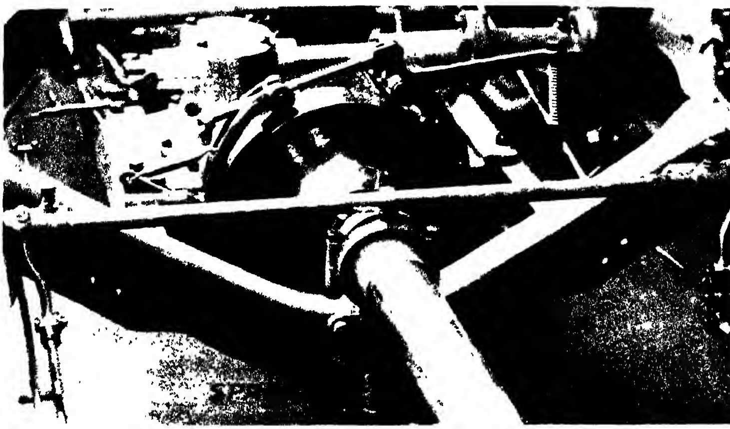
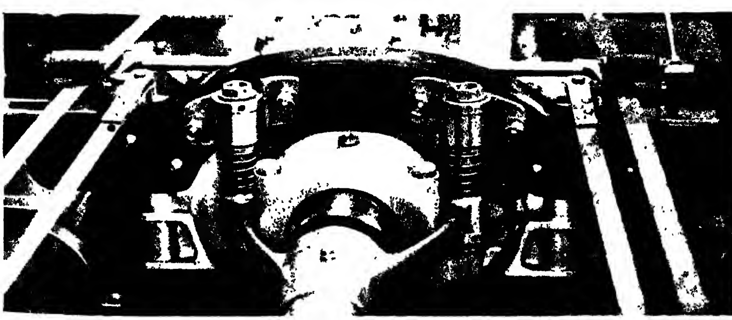
Diagrammatic sketches illustrating various systems of connecting the back axle to the frame.

the joints in the propeller-shaft, it is impossible to use this member itself as a strut between the axle and the frame; but, very frequently, the springs are used in this capacity. Sometimes, however, separate hinged radius rods, fastened







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SUPPORTS FOR PROPELLER-SHAFT CASINGS

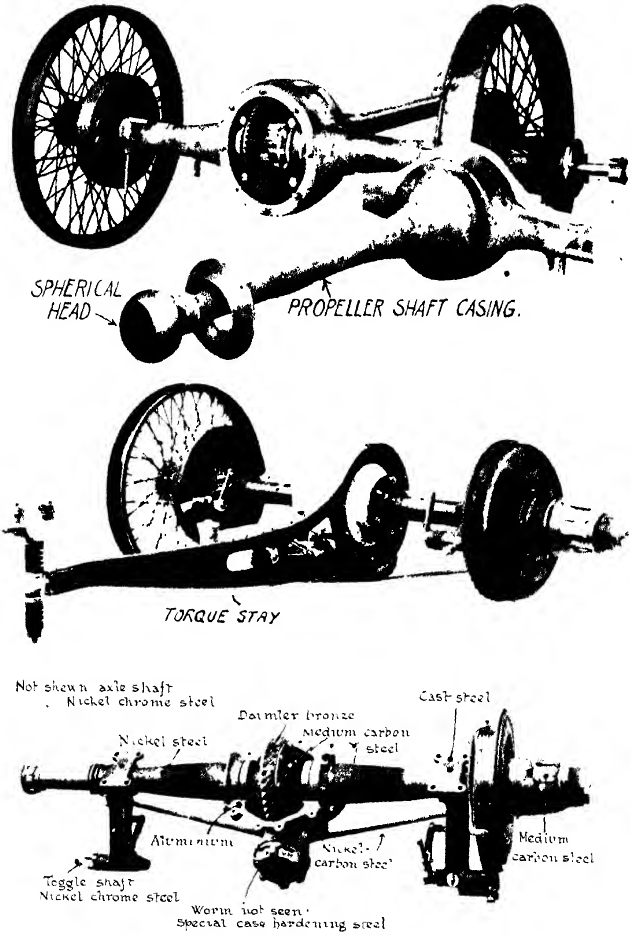
When the propeller-shaft is enclosed by a tubular casing, various modes of supporting the upper end of the casing are in vogue. The upper view shows the casing riding on the propeller-shaft itself. The central photograph shows it supported upon a spring buffer, and in the lower picture it is similarly suspended by the use of a forked extension. The cars in question are a Talbot, a Humber and a Panhard, in the order mentioned.

to the side members of the frame and to the extremities of the axle-casing, are employed, and when the springs are used as radius rods it is obviously necessary that they should be directly hinged to the frame at their front ends, and not be mounted on shackle links.

Another method of transmitting the thrust of the road wheels to the chassis, is to use the propeller-shaft casing as a radius rod by fitting its upper end with a spherical head that is supported in a cup attached to one of the transverse members of the main frame. There are, in fact, a variety of combinations that can be used, and the more important of those that have found practical expression in chassis design are illustrated diagrammatically in some accompanying sketches.

In addition to the need for radius rods, there is, as has also been explained in a preceding chapter, the need for using a torque stay in order to resist the tendency of the axle-casing to rotate backwards. Frequently, this torque stay forms a separate member mounted alongside the propeller-shaft. It is rigidly secured to the axle-casing, but is commonly suspended on a spring buffer in front. In other designs, the propeller-shaft casing serves the purpose of a torque stay. Sometimes it is independently supported at its upper end on spring buffers, and sometimes it rests on the propeller-shaft itself. In this latter

case the torque comes upon the gear-box bearing through the universal joint. Where there is no independent torque stay of any description, the torque is resisted by the rear springs, which must be mounted on brackets that are rigidly secured to the axle-casing. When a separate torque stay is fitted, the spring bracket may ride on the axle-casing.



THREE EXAMPLES OF BACK-AXLE DESIGN

The upper view shows a Crossley bevel-driven live rear axle; the central view illustrates a Napier worm-driven axle, and the lower photograph shows a Daimler worm-driven axle. The various materials employed in the construction of the axle are indicated on the lower photograph. The torque-stay on the Napier axle is a prominent feature, likewise its spring-buffer suspension. In the Crossley design, the spherical head on the propeller-shaft casing serves the purpose of a torque-stay as well as a radius-rod. In the Daimler design, the rear spring serves both purposes.

CHAPTER VI

BRAKES

IT is unnecessary to say much about the construction of the brakes, as their action can so readily be examined on any car. The foot-brake most commonly operates upon a drum mounted on the gear-shaft immediately behind the gear-box, and, as a rule, the hand-brakes operate on drums bolted to the spokes of the rear wheels. These two rear-wheel brakes operate simultaneously by the application of a single lever, and the pull of the driver's hand upon the lever is divided equally between the two brakes by a compensating gear, which, in earlier chassis design, was usually a length of steel cable, but in modern cars is more often provided by some form of pivoted rocking bar.

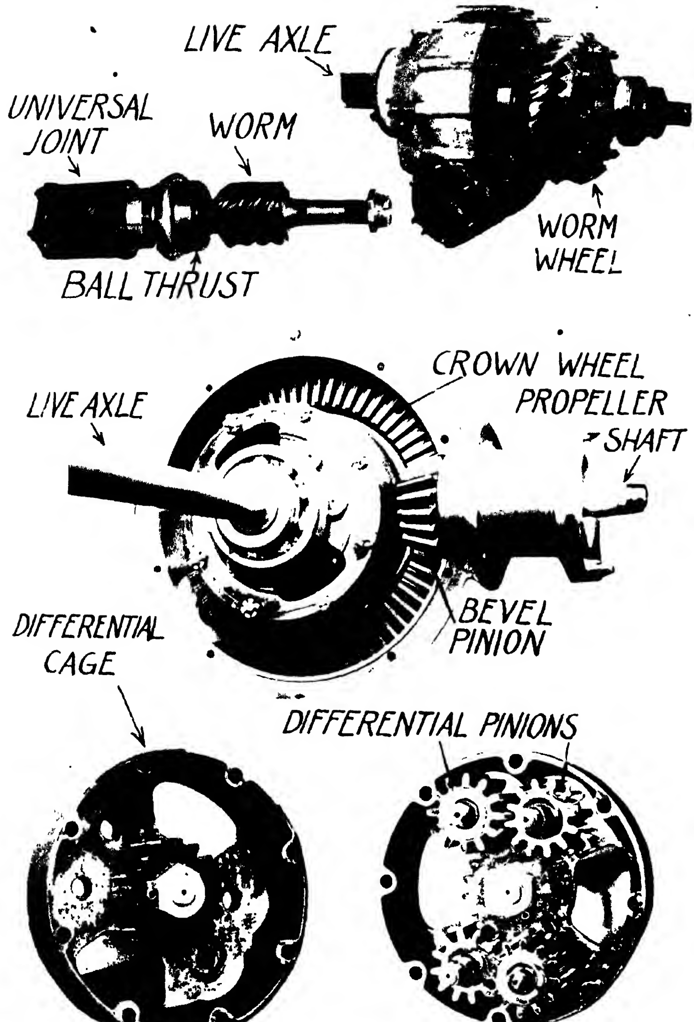
The interconnection of the brakes by this means compensates the pressure with which they are applied, but it does not compensate the brakes in the full sense of the term as it is understood by those who suppose that the system affords an equalized braking effect on both wheels.

If for any reason one drum offers a better grip for the brake-shoes than the other drum, the

retarding effect of that wheel will be greater than the retarding effect of the other wheel, in spite of the compensated application of the brakes. In order to compensate the true braking effect it would be necessary to compensate the anchorages or supports of the brake-shoes, but this would introduce a complication that is hardly worth while.

Some while ago, considerable interest was taken in the use of brakes on the front wheels of the car, and several firms introduced models thus equipped. The potential advantage of the system is considerable. It improves the "pulling-up power" of the car by employing the grip of four wheels instead of two, and the adhesion due to the whole weight of the car instead of that part only which is supported by the back axle. Also, the application of front-wheel brakes does not tend to promote skidding under conditions that would be prone to do so were the rear-wheel brakes applied.

This connection between front-wheel brakes and non-skidding qualities is concerned with the natural tendency of any moving object to follow the path of least resistance. In a free-rolling wheel, the direction of rolling is ordinarily the line of least resistance, whereas if the wheel has lost its adhesion on the ground it will slide in the direction in which it is momentarily propelled by the momentum of the mass of the car.



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THE COMPONENT PARTS OF TWO DESIGNS OF BACK-AXLE DRIVE

The upper photograph illustrates a worm gear from a Napier car; the other photographs were taken at the Vauxhall works, and the central one shows a typical bevel-drive. The lower photograph illustrates the interior of the differential gear. The differential gear illustrated is of the parallel pinion type. The differential pinions, which are supported on pins fixed to the differential cage, mesh with each other. One of them also meshes with the central spur-wheel on one half of the live axle-shaft. The other differential pinion of the pair engages with the opposite central spur-wheel on the other half of the live-axle shaft.

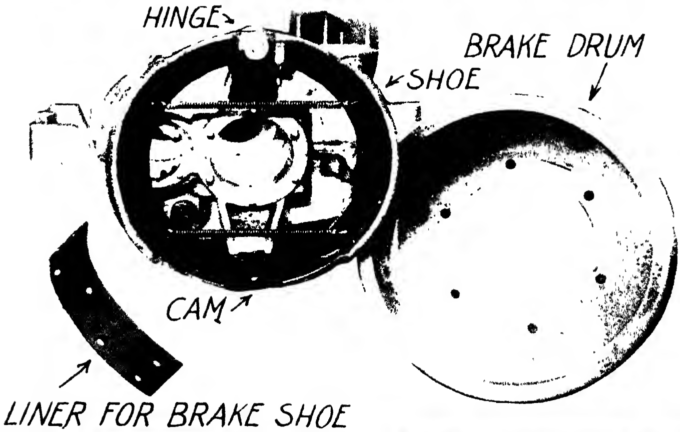
If the rear wheels of a car lose their adhesion, and the car is at the same moment steered a little to one side, the back of the car tends to continue in its original direction, which causes the vehicle to skid sideways, or even to turn completely round in the road. If, however, it is the front wheels that lose their adhesion when the brakes are applied, they continue in their original direction, and the rear wheels roll after them without tending to move sideways. Thus the car as a whole slides bodily forward, but it does not slide sideways or tend to turn round in the way that a sideslip is ordinarily understood. There are, of course, conditions in which a front-wheel skid is every bit as bad as, if not worse than, a back-wheel skid ; and it is, in fact, very largely because front-wheel brakes tend, in the limit, to lock the front wheels and so to make the car unsteerable, that they have never been received with universal favour.

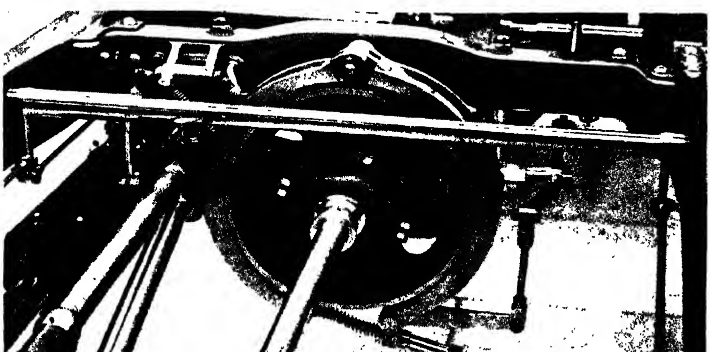
Moreover, it was found by experience that it was exceedingly difficult to equalize the braking effect of the two front wheels, and, in consequence, there was, in many instances, a strong tendency for the application of the front-wheel brakes to react upon the steering in a manner that, if not exactly dangerous to an experienced driver, was, at any rate, sufficiently inconvenient to be undesirable.

Radius rods also have to be fitted to the front axles of cars that have front-wheel brakes, and

there is a tendency for this to make the riding of the front part of the car seem hard on a bad road. Difficulty is also experienced in so devising an operating mechanism that it shall not transmit a jerky movement from the brakes to the pedal. It will be understood, of course, that the brakes themselves, as well as the operating mechanism, have to be arranged so as not to interfere in any way with the free steering movement of the wheels, and it is also a matter of some difficulty to retain the full amount of the steering lock.

Among the firms that studied the problem, the most persevering was Messrs. Argyll, who ultimately evolved a system of diagonal compensation whereby the front-wheel brake on one side and a rear-wheel brake on the other side of the car were interconnected. This arrangement was found to overcome many difficulties, particularly if care is taken to adjust the rear-wheel brakes so that they make contact a shade before the front-wheel brakes. At the time of writing, the Argyll car is practically the only well-known make on which front-wheel brakes of any description are retained. As is usual with brakes acting directly on the road wheels, some force is required to produce the initial grip, but the advantage of all four wheels acting simultaneously is subsequently very marked.





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TYPICAL FOOT-BRAKES

The upper photograph shows an enclosed expanding foot-brake on a De Dion car, the lower view illustrates an external contracting foot-brake on a Wolseley car. In the first case, the shoes expand outwardly against the interior surface of the drum, and in the latter case they embrace the outer rim of the drum. In the centre is a photograph showing details of the expanding foot-brake on the Vauxhall car. The hinge that supports the shoes and the cam that forces them apart and

CHAPTER VII

STEERING

THERE is no other part of the transmission mechanism of the chassis that calls for much detailed description, for the action of such other members as find a place on the modern car is to all intents and purposes self-evident. The existence and purpose of the radius rods and torque stay are discussed in a former chapter, and so far as the transmission is concerned, they complete the system.

There is, however, perhaps one part of the general construction of the car about which something further may with advantage be said, and that is the steering mechanism.

All cars, with perhaps one or two exceptions in the very early days, have used the same system of steering, which is commonly known as the Ackermann steering, but was, in fact, the invention of Herr Lankensperger, of Munich, in 1819, Ackermann having merely acted as patent agent in this country.

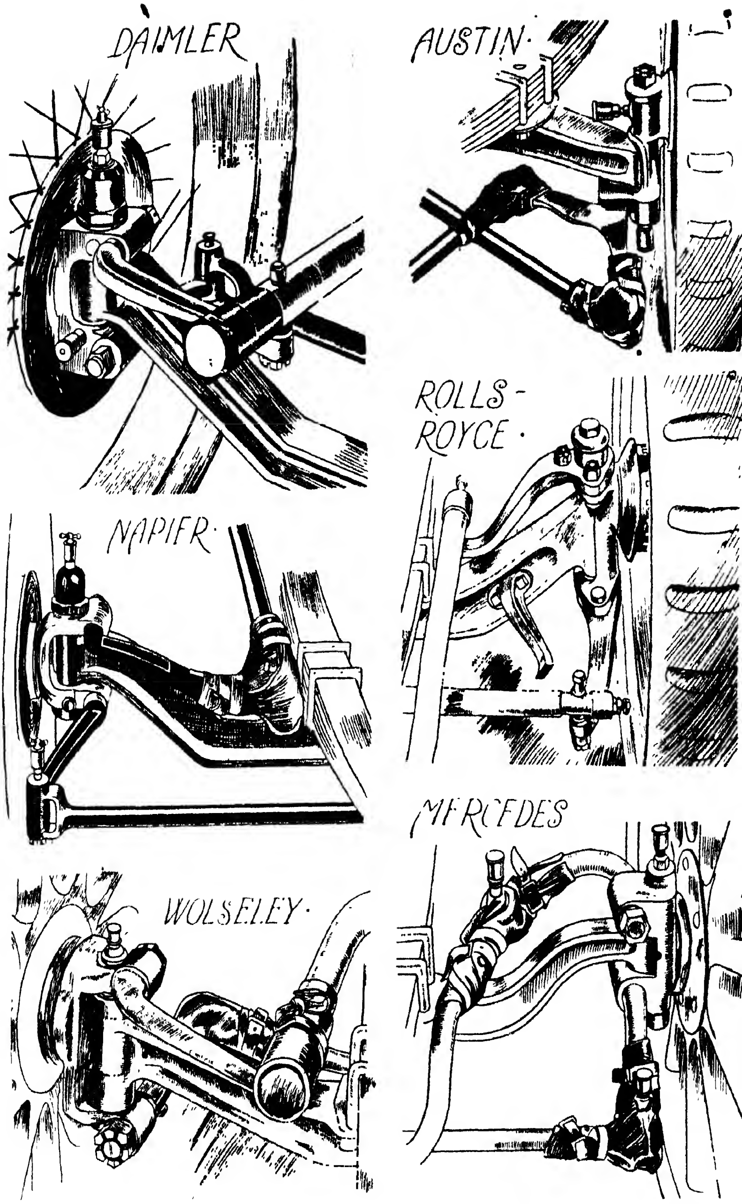
At the time of its first introduction, it met with a very unfavourable reception at the hands of the coachbuilders; indeed, it had no particular advantages in connection with the horse-drawn

vehicle, for which it was, of course, at that time introduced. In the case of the motor-car, however, there has scarcely been a single invention of greater utility and merit, and it is certainly a pity that neither Lankensperger nor Ackermann can have derived more than a ghostly interest in the success of the system that they introduced so much before its time.

No vehicle could possibly be driven at the speed that is now safely attained by every modern car but for the Ackermann steering, for to have attempted to do so with the turntable system that is in vogue on horse-drawn vehicles would speedily bring disaster to the average driver.

In the turntable system of steering, the wheels are mounted on a solid axle, which is itself so erected that it pivots about its centre, on a turntable. In the Ackermann system of steering, each wheel is mounted on a short stub-axle that is independently pivoted to the extremity of the main axle; the main axle itself, in the Ackermann system of steering, does not move.

One immediate result of this arrangement is to very much reduce the amount of movement that is required in steering, and there is a consequent increase in the steadiness of the steering control. Another incidental result is that much larger wheels can be used, and this itself reacts in favour of steadiness, which is the keynote of the Ackermann system.



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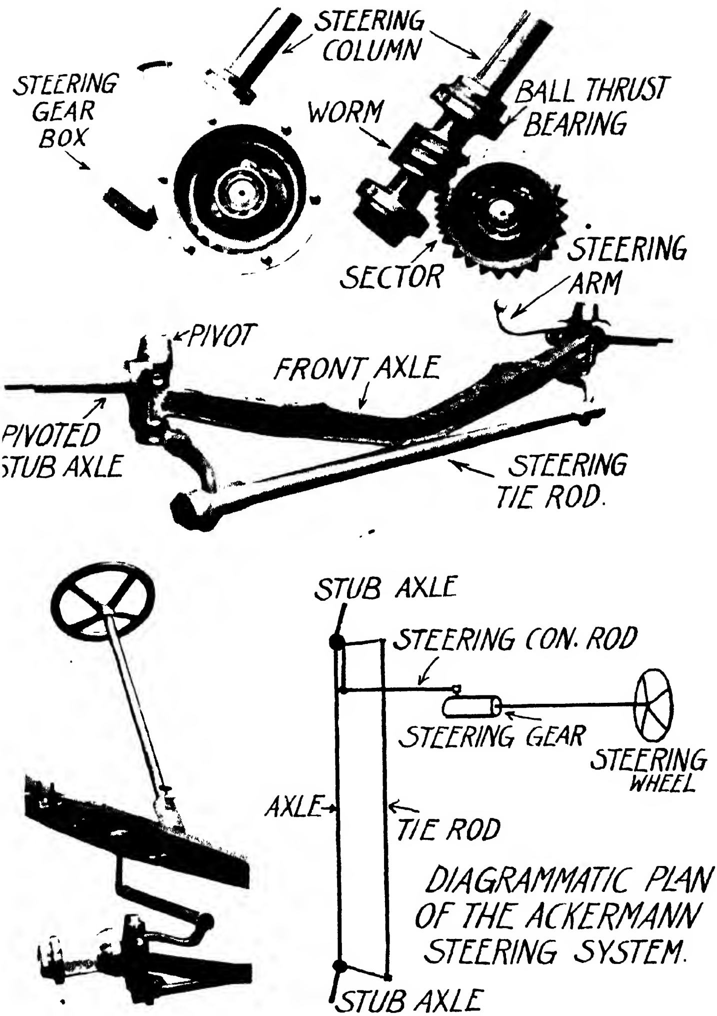
Methods of fastening the steering connecting-rod to the steering-arm. This is one of the really vital points in the chassis.

There are one or two technical points in connection with Ackermann steering to which it may not be without interest to draw attention, as there is such a very good reason why the private owner should feel concern about the steering of his car. Any inaccuracy in the design of the steering connections immediately makes itself felt on the life of the tyres, and this in turn at once affects the owner's pocket.

When a car follows a curved path, its front wheels should both be at right angles to radii of concentric circles, and the centre of those circles should be situated on an extension of the axis of the back axle. It will be observed (Fig. 2) that the front wheels are no longer parallel to one another when the car is following a curved path of this description; if they were parallel to one another they would not be tangential to concentric circles, and they would not be conforming to the true principles of steering. This disposition of the front wheels, whereby they are caused to turn unequal amounts so as to keep them always tangential to concentric circles, is obtained by making the steering connecting-rod, A, longer than the distance between the steering-pivots, B (Fig. 1), and it is one of the principal problems requiring solution to know how much longer the steering connecting-rod should be made in order to produce the desired result. If it is too long or too short the wheels will be tangential to circles



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THE STEERING MECHANISM OF A CAR

The photographs were made at the Vauxhall works.

that are struck from different centres, so that one side of the car will try to follow a different path from the other, with the result that the mean course pursued by both wheels will cause a frictional rubbing of the tyres over the ground.

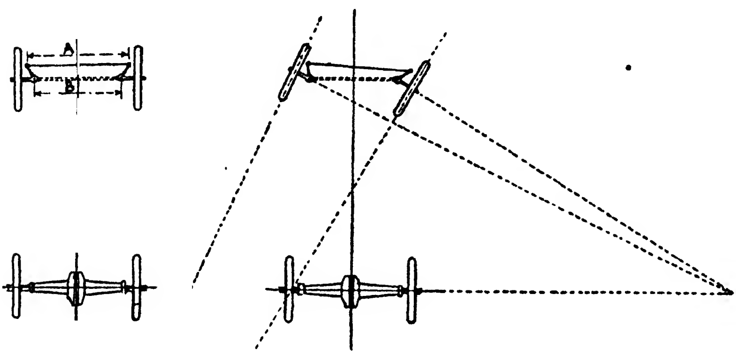


Fig. 1. Fig. 2. "*Auto*" *Copyright Drawings.*

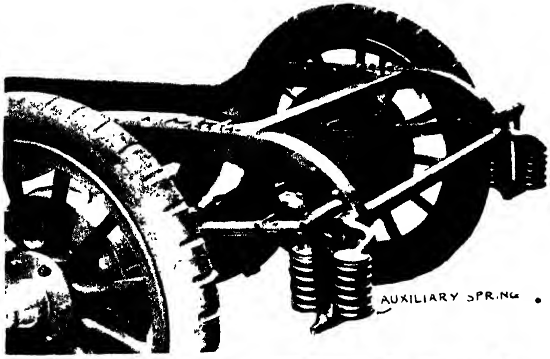
Diagrams illustrating the principle of the Ackermann steering. Fig. 1 shows the car proceeding straight ahead. It will be observed that the tie-rod A is longer than the axle B between the steering pivots. The effect of this difference in length is to cause the front wheels to turn differently in amount when they are steered, but each remains approximately tangential to circles described from a common centre. The wheels thus perform a true rolling motion when following a curved path. If they were tangential to different centres, one wheel would have to slip sideways a little while rolling, which would speedily wear out the tread of the tyre It is also important that the centre of the turning circle should lie on a projection of the axis of the back axle, otherwise the rear wheels will tend to skid. If the tie-rod A is placed behind the axle B, it must be made shorter in length in order to give the same effect.

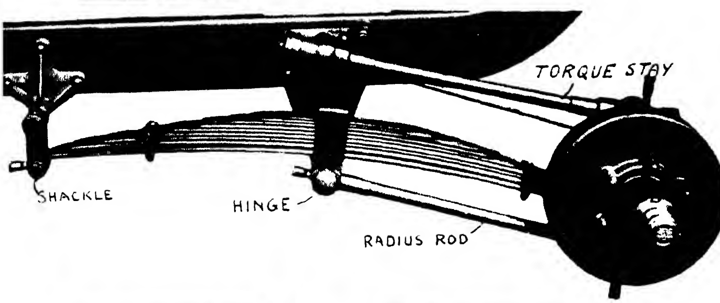
The importance of this matter from the owner's point of view can only properly be appreciated when it is borne in mind how continually the car is being steered a little to one side or the other even on a straight road. If the steering arrangements are not true there is a slight amount of unnecessary friction every time that the steering-wheel is moved, and so much the more rubber is abraded from the tread of the tyre.

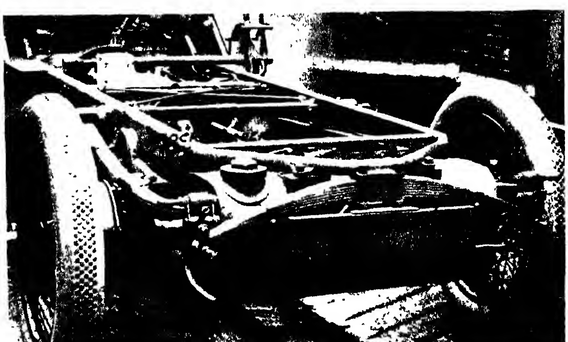
CHAPTER VIII

SUSPENSION

THERE is no more important matter to the motorist than the suspension of his car, and its significance increases in proportion to the increase that has taken place in the reliability of automobile machinery. It is a subject, nevertheless, that has received singularly little attention considering the place that it ought to occupy in the literature of motoring technology. Those outside the automobile industry might reasonably be pardoned for supposing the technical details of the suspension of a vehicle to be the sole concern of the engineer responsible for the machine's construction, but the enormous business done by the private motorist with the accessory dealer in auxiliary springs and shock-damping devices will suffice to satisfy any thoughtful person that the study of the problem of car suspension is by no means limited to automobile designers as a class, and, when such an immense number of motorists as do undoubtedly buy auxiliary suspension devices are anxious to tamper with the original springing







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THREE INTERESTING TYPES OF SUSPENSION

The upper view shows auxiliary springs on a Daimler chassis. The centre picture illustrates the Lanchester type of cantilever spring on the Siddeley Deasy chassis. The lower photograph represents a Napier chassis fitted with a transverse spring joining the rear ends of the two side springs.

of their vehicles, it surely stands to reason that there is still room for some improvement.

The suspension of cars is good, bad, and indifferent, and the trouble is that no one seems to quite know what constitutes the essential difference between the three classes. The question is, What is " right " ? and that is just where experts are either silent or in discord.

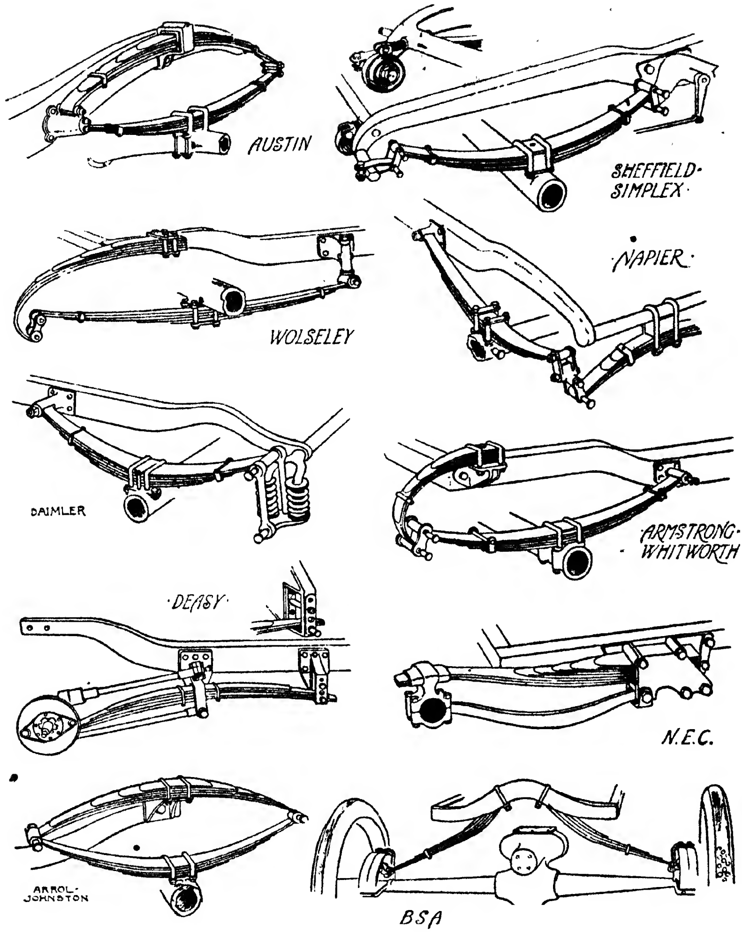
In a paper read before the Institution of Automobile Engineers by Mr. G. H. Baillie in 1913, the author adopted change of acceleration as the criterion of discomfort, and this is worthy of special attention as a matter of general information for the reason that the human frame is only sensitive to changes of acceleration, and neither to acceleration nor to velocity as such. This is, for example, a matter of some importance in connection with the control of aeroplanes at great altitudes, where the pilot is alone in space. If a change in his attitude happens to pass unnoticed it may quite conceivably remain uncorrected, and he thereby rendered oblivious to a dangerous position.

In discussing the paper, Mr. H. E. Wimperis—who is a recognized expert on phenomena relating to acceleration, and whose accelerometer is a particularly interesting instrument for car testing and the like—argued that it was not the change of acceleration in the absolute, but the rate of the change of the acceleration that determined whether the dis-

turbance would be a source of discomfort to the passenger. He instanced, as an example not directly bearing on motoring, the interesting fact that railway engineers, when laying out the curves of tracks, endeavour not to exceed a rate of change of acceleration of 1 foot-per-second-per-second-per-second. The rate at which the acceleration changes in the starting and stopping of the electric trains on the "Tube" may reach values as high as 50 feet-per-second-per-second-per-second, and a value of this order is undoubtedly uncomfortable.

These considerations are of great general interest, and need to be borne in mind by those who study the problem of springing; the difficulty is to know how to express them quantitatively as a problem that shall lend itself to definite solution. Ordinarily, the periodicity of a suspension system is regarded as a concise inclusive summary of its salient features. The natural period of a resilient system is determined by the extent of its normal deflection under the load. For example, a spring that is compressed 4 inches when the passengers are in the car will vibrate naturally at a rate of 96 alternations per minute. If it is deflected by a temporary pressure that is suddenly released, the spring will extend to its original condition in 0·16 second.

If the wheel rolls over an obstacle at such a slow rate that it requires the above interval of time, or



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Sketches illustrating various systems of suspension, with particular reference to the methods employed for supporting the frame above the back axle.

longer, to rise to the top of the obstacle, it is evident that the spring will transmit the motion to the body of the car as if it were a solid link.

Alternately, if the rate at which the wheel surmounts the obstacle is less than the natural rate of extension on the part of the spring, it is evident that the spring will be unable to transmit the whole motion as a link, but it will in fact absorb some of it by compression. For example, a 30-inch solid-tyred wheel on a car travelling at 30 miles an hour will rise to the top of a 3-inch brick in 0·018 second.

I have sometimes suggested that the ratio between these intervals of time, which in this case has a numerical value of 8·9, might be of some service as a basis of comparison, because it brings into consideration the wheel diameter and the speed, both of which are well known to be of first-class importance as factors affecting comfort.

Anyone who has had any considerable experience of motoring knows very well that the driver is a most potent factor in the suspension system. A road that is bad he can never make good, but that does not in the least prevent him from making it utterly horrible: it is everything when driving a car to suit the speed to the road. On a road that is really almost too bad to be used at all a sharp zigzag course will reduce the discomfort and also the danger of damage to a marked degree.

Another factor of much importance in this subject, is the influence of friction in leaf springs. The leaves of a plate spring rub over one another whenever the spring is deflected, and as the springs of most motor-cars are generally allowed to get rusty, the friction in the system may reach a considerable value.

It is apparent that this friction is not resilient, and whatever merit it may possess in respect to its ability to damp out oscillation, there can be no question that it tends to transmit a greater proportion of the initial shock. In short, it constitutes a solid link in the system, albeit one that does not wholly place the main springs out of action.

It is interesting and important to observe in this connection, however, that the influence of this frictional link does not always bear the same relative value, for the reason that obstacles of different heights do not produce the same rate of vertical acceleration on the wheel.

Thus, for example, if the 3-inch brick of our preceding hypothetical case subtends an angle of 36° between the point of its contact with the tyre and the point of the tyre's contact with the road, it will be found that halving the height of the obstacle will not be accompanied by a similar reduction in the subtended angle. The angle subtended by a 1½-inch brick will, in fact, be considerably more than half the angle subtended

by a 3-inch brick—that is to say, the smaller obstacle will strike a disproportionately lighter blow.

This is, of course, all in favour of the smaller obstacle from the standpoint of potential improvement in road construction, but at the same time it must be remembered that the friction of a spring; which, being a resistance, itself has the dimensions of a force, now bears a higher relative value than before, and the relative influence of its ability to transmit the axle movement as a solid link is likely to be more pronounced.

Putting this into other language, I may say that a car that would be considered well sprung for fast touring, even on indifferent roads, might be quite likely to feel relatively uncomfortable at slow speeds on apparently good roads. If this is true —and my experience of cars leads me to believe that there is something in the idea—then what is most required is a frictionless auxiliary suspension specifically designed for absorbing small obstacles. It is in this light that I have always regarded the supplementary helical springs with which it has been customary of late to fit motor-cars.

I do not by any means suggest that this is a proper solution to springing in general, or that all cars can be improved by auxiliary springs or even that all auxiliary springs now on the market are designed to offer the advantages that I have outlined. I do suggest, however, that some cars may

reasonably be expected to be improved for certain purposes by such fittings, and that the nature of the improvement relates to the explanation that I have just given.

The design and construction of springs are related to a special department of the subject of suspension that should properly be treated separately, but I purpose passing over this phase of the subject with a mere reference to the illustrations and to matters of such importance as the number of leaves, the camber, the tempering of springs, and the necessity for adequate weight of metal to prevent fatigue and fracture.

A matter that bears upon the suspension problem generally, inasmuch as it constitutes an additional argument emphasizing its importance, is tyre wear. The wheel is jerked off the road by an obstacle, and, whilst in the air, is able to increase its rotation under the driving power of the engine acting through the differential. When it comes into contact with the road again, this extra spin has to be retarded, which is, of course, all at the expense of the tread of the tyre.

One of the factors that determine the height to which the wheel rises clear of the obstacle, and, therefore, the time that is available for its speeding up in space, is the weight of the axle plus that portion of the spring carried upon the axle. If the unsprung weight is heavy, the rise of the wheel is likely to be excessive, and considerable tyre

wear may take place in consequence. Lightness of axle weight, without sacrifice of strength, is, therefore, a desirable feature, and one notable means of decreasing the unsprung weight is to employ the Lanchester system of suspension.

In so far as the natural periodicity of the system is regarded as a broad criterion of comfort, and in so far as this is determined by the normal deflection under the load, it is apparent that structural considerations such as the height of the frame above the axle and the clearance of the body above the wheel introduce limiting factors into the consideration. Speaking generally, the more flexible the spring the more comfortable the suspension, and it may be assumed that any system with a natural period exceeding 100 vibrations per minute is likely to feel harsh.

In respect to the merits of flexibility, however, I should like to qualify my remarks by referring back to the importance of considering the conditions under which the car is driven—to point out, for instance, that the equivalent spring for a racing car driven at high speed on Brooklands track is by no means identical with that employed for ordinary touring conditions.

Furthermore, my own experience has been such that I do not altogether favour a too flexible spring above the front axle. I prefer to feel the character of the road over which I am driving, and, in general, I incline to the idea that it is safer to provide this

warning for the average chauffeur. If the front suspension is so exceedingly flexible as to smooth out a really bad road, it is not altogether unlikely that an unthinking driver may injure his springs before realizing the serious strains to which he is subjecting them.

So far as the rear springs are concerned, they cannot be too comfortable, but this is not to say that, as at present arranged, they cannot be too flexible. It must be remembered that a spring takes no cognizance of the source of its deflection, and if the force deflecting it comes from above, as in the case when a car is turning a corner at a high rate of speed, it will be equally ready to compress. In doing so it will give rise to that rolling motion to which most passengers very strongly object.

When this takes place with the front springs, it is not only uncomfortable, but may even be dangerous, for it makes accurate steering of the car a matter requiring unusual skill.

There is, it will be seen, a commercial consideration restricting the development of very flexible suspension systems for cars, for their influence on motorists who take their machines far afield and spend a great deal of their time driving fast, is by no means certain to be altogether favourable. It is, in fact, a compromise that best serves the purpose of the majority, but there is, as I remarked in the first instance, some evidence that

the compromise at present ruling is not up to the standard of general requirements.

In this matter, a subsidiary solution of utility will be found in the improvement of the upholstery. The deep-seated cushion with long interior springs is a most comfortable fitting, and although it is not cheap, it is thoroughly well worth the money. It is necessary for the manufacturer of the car as well as the builder of the coachwork to make provision for these deep-cushion seats; but I believe that if the automobile trade brought their virtues more to the notice of customers than is done at present, it would remove a great deal of the present dissatisfaction with the existing springing. Many a car that is well enough sprung for all-round purposes might readily be adapted to meet the requirements of the fastidious by the addition of this refinement, and the alteration would have the advantage of leaving the chassis design unchanged.

In this chapter I have found space to touch only upon one or two factors relating to a very wide and very intricate subject, and I have not even mentioned the important influence that the attachment of the springs to the frame has on the general riding of the car. This book, however, is not intended to be a technical treatise, and it is necessary to omit much that is of genuine interest in the detail of chassis design.

CHAPTER IX

THE PETROL ENGINE

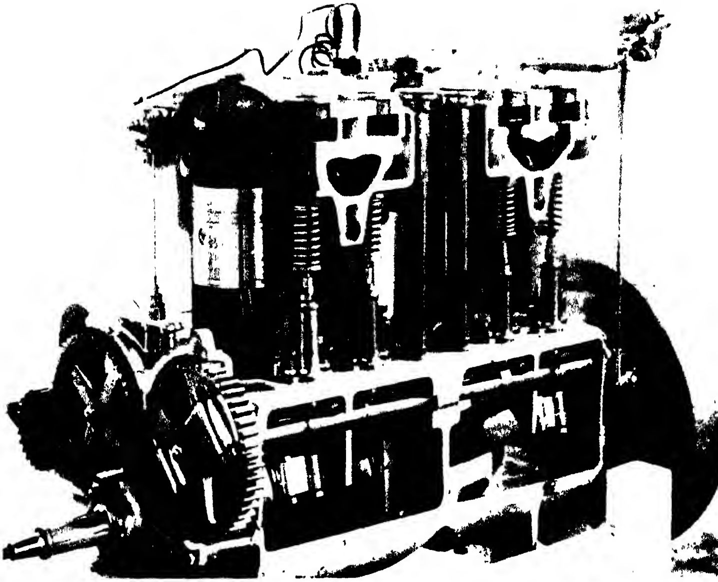
THE petrol engine is a specialized form of gas engine, and belongs to the great class of internal combustion engines, which differ from steam engines in that the fuel itself is consumed inside the engine instead of in the furnace of a boiler. In a steam engine, the steam is a fluid medium enabling the heat of the fire to be converted into work. In the petrol engine, the heat, which is the source of all the work, is derived from the explosion of a mixture of petrol vapour and air. The explosion takes place inside the cylinder of the engine, and the force of the explosion is directly communicated to the piston, which is one of the principal mechanical members of all reciprocating engines.

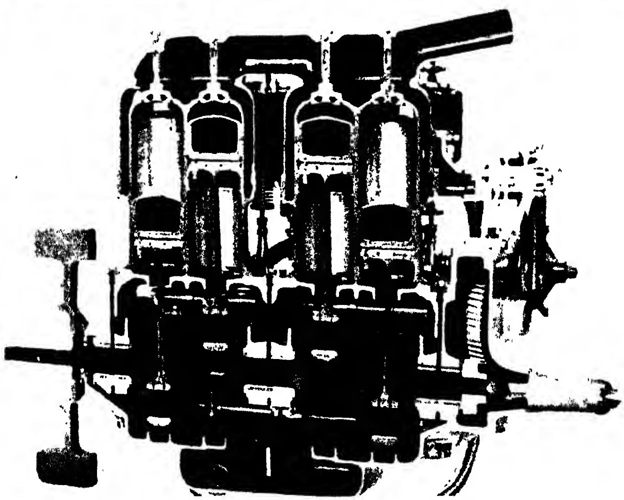
The principal parts of the petrol engine are the cylinders, of which there may be any number grouped together to form one engine ; the pistons, of which there is one in each cylinder ; the crank-shaft, which is the member employed to convert the reciprocating motion of the pistons into the rotary motion that is so much more useful for all practical purposes ; the connecting-

rods, which form links between the pistons and the crank-shaft; and the valves, which serve to regulate the admission and exhaust of the explosive mixture to and from the cylinders.

There are also a number of essential but, so far as first principles are concerned, supplementary parts, such as the cam-shaft, which operates the valves; the magneto, which generates the electric spark that ignites the explosive mixture; the carburettor, which is a device that atomizes the fluid petrol and mixes it with air, so as to form an explosive gas; the circulating-pump, which maintains a flow of water through jackets surrounding the cylinders, in order to prevent them from overheating through the high temperature of the explosion; and the oil-pump, which maintains a film of oil between the crank-shaft and the bearings that support it, and in a similar way assists in reducing friction by the lubrication of other moving parts.

Some of these supplementary parts are not always present in the form described, being occasionally substituted by corresponding members performing a similar function in a different way, and sometimes even being absent altogether as, for instance, in the case of air-cooled engines, which have no water-jackets, and thermo-syphon circulation systems, which have no pump. In these latter, the water circulates as the result of the natural tendency of hot water to rise to the highest





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ENGINE INTERIORS

The upper view shows an old Berliet engine, fitted with low-tension ignition, but this photograph still remains one of the clearest illustrations that have ever been prepared to show the interior mechanism of a motor. The lower view illustrates a Wolseley engine that has been cut in half down the longitudinal axis.

point in the system. Often, too, an oil-pump is not used, oil being carried in the base-chamber of the engine at such a level that it is splashed over everything inside the engine by the rotation of the crank-shaft.

Petrol engines operate upon either one of two systems, or "cycles," which are known as the 4-stroke cycle and the 2-stroke cycle. The majority of petrol engines, however, operate upon the 4-stroke or Otto cycle—which was devised by Beau de Rochas in 1862.

The essential difference in principle between the 4-stroke engine and the 2-stroke engine is that in the cylinder of a 4-stroke engine an explosion takes place once every four strokes of the piston (a stroke is a movement of the piston up *or* down), corresponding to two revolutions of the crank-shaft, whereas in the cylinder of a 2-stroke engine an explosion takes place once every two strokes of the piston, corresponding to every revolution of the crank-shaft.

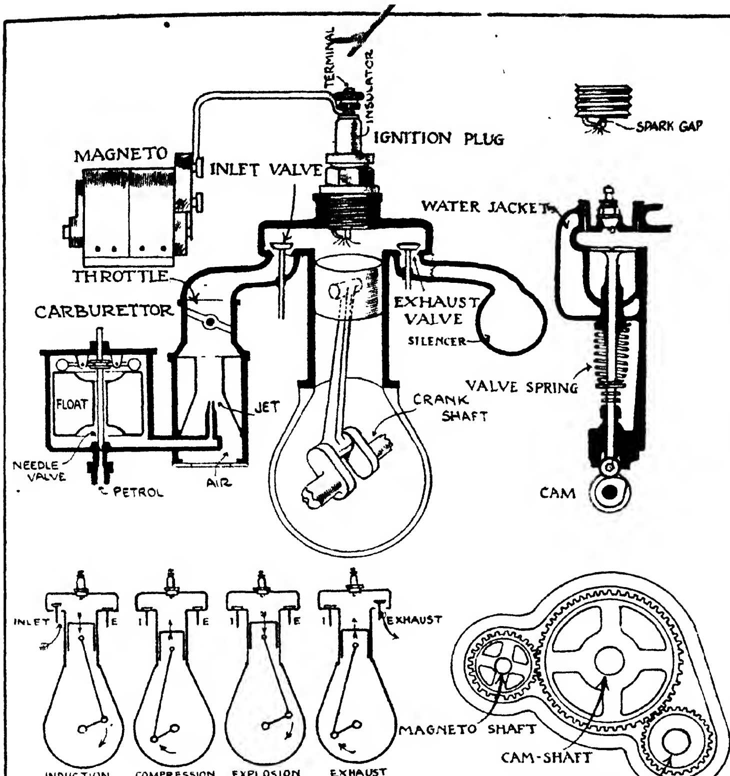
Inasmuch as the explosion is the sole source of power, it would seem that the 2-stroke engine is apparently capable of affording twice the power from given dimensions and given weight; also that, in principle, the regularity of the turning moment on the crank-shaft will be superior to that obtaining in a 4-stroke engine, because of the relatively greater frequency of the explosions in a given time. This is, of course, assuming that

both engines operate at the same revolutions and have the same number of cylinders.

In practice, however, the line of least resistance to progress has hitherto been found to lie in the direction of the 4-stroke motor, which has, therefore, been developed very much more than the other type. The irregularity of its turning moment has been compensated by increasing the number of cylinders, until engines in modern use now seldom have less than four cylinders. Those employed on motor-cars often have six cylinders, and those used on aeroplanes frequently possess eight cylinders or more.

Motor-car practice has been to place the cylinders vertically and in line with one another. The aeroplane engine, however, often has its cylinders arranged at an angle to one another, such engines being said to belong to the V type. The special requirements of aviation, which necessitates extreme lightness of construction in proportion to the power developed, have also resulted in the evolution of other special types of petrol engine, of which the rotary motor is the most notable. In a rotary petrol engine, the principal members are unchanged; but the cylinders are placed radially like the points of a star around the chamber enclosing the crank-shaft, which chamber, together with the cylinders, rotates bodily about the fixed crank-shaft.

The actions and reactions in a rotary engine



THE BEAU DE ROCHAS OR OTTO 4 STROKE CYCLE

"*Auto*" *Copyright Drawing.*

Diagrammatic drawing illustrating the elements of a petrol engine. The piston, connecting-rod and crank-shaft are shown in perspective in a cylinder that is shown in section. Below, is a series of diagrams illustrating the four strokes of the Otto cycle. During the suction stroke, the descending piston acts as the plunger of an air-pump to draw air from the atmosphere past the throttle valve and the inlet valve into the cylinder. Flowing through the contracted choke-tube surrounding the jet of the carburettor, the air causes petrol to spray therefrom, and thus becomes carburetted with its vapour. The mixture thus formed is explosive when compressed by the return stroke of the piston. As the piston reaches the top of its compression stroke, a spark occurs at the ignition-plug, thus starting combustion in the gaseous mixture. Combustion is propagated through the gas so quickly as to cause explosion, and the consequent rise in temperature results in expansion of the burning gas, and also of the inert nitrogen of the air, which does not enter into the combustion. The piston is thus driven to the bottom of the cylinder, and performs the one working stroke of the cycle. During the return stroke, the burnt gases are expelled through the exhaust valve into the silencer. The valves are generally mechanically opened by cams mounted on a shaft that is gear-driven from the crank-shaft. The closing of the valve is effected by a spring.

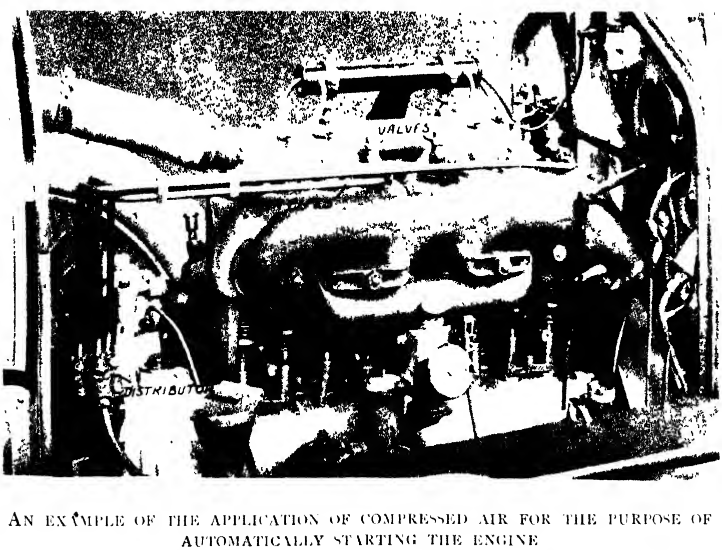
are fundamentally similar to those in a stationary engine; that is to say, the explosion pressure on the piston operating upon the crank through the oblique line of the connecting-rod sets up a couple causing either the crank-shaft or the cylinders to revolve as the case may be. The majority of engines are of the stationary type, by which is implied that the crank-shaft revolves and the cylinders with their base-chamber are fixed.

The four strokes of the four-stroke or Otto cycle of operations followed by the majority of petrol engines, correspond to four definite periods that occur in an invariable sequence. The starting-point assumes the piston to be situated at the upper end of its stroke, that is to say, adjacent to the closed head of the cylinder. External force is employed to draw the piston down the cylinder to the lower end of its stroke, which external force is initially provided by the muscular effort of cranking the engine by hand when starting up, but is afterwards provided by the momentum of the fly-wheel or other equivalent revolving mass, such as the propeller in the case of an engine on an aeroplane, where fly-wheels of any appreciable size are seldom fitted.

This down stroke or period in the cycle of operations is known as the suction stroke, because during this time the engine acts in the capacity of a pump for the purpose of drawing into its cylinder, by the suction effect of the piston acting

SECTIONAL PHOTOGRAPHS ILLUSTRATING THE INTERIOR OF THE INLET AND EXHAUST PIPES

Gas from the carburettor flows through the induction pipe, which is branched so as to communicate with the valve chambers. In a four-cylinder engine the inlet valves are adjacent in pairs and each pair communicates with a common chamber. The exhaust valve chambers are separate, but they all discharge into a common pipe



AN EXAMPLE OF THE APPLICATION OF COMPRESSED AIR FOR THE PURPOSE OF AUTOMATICALLY STARTING THE ENGINE

The apparatus is seen above in place on one of the cars built by the Wolseley Co. A group of pipes lead from a distributing valve to independent atmospheric valves carried by the inspection caps over the exhaust-valve chambers. The distributor is mechanically driven from the cam-shaft, and admits compressed air from a reservoir in proper sequence to the cylinders. The air is admitted during what otherwise would be the firing stroke. The reservoir is charged by a small compressor, also driven by the engine.

as a pump-plunger, a charge of explosive mixture. In the earlier types of engine, the charge was admitted through a simple spring-loaded valve that also opened as the result of the suction; modern engines, however, have mechanically operated inlet valves, and the supplementary mechanism that controls them is adjusted to time the opening so as to give the best results. In practice, the inlet valve is, as a matter of fact, opened a little before the piston starts to descend, that is to say, it is opened during the last phase of the preceding stroke, which will presently be described.

When the piston has reached the end of the suction stroke and the crank-shaft has, therefore, made half a revolution, the inlet valve is closed, thereby sealing the charge in the cylinder. In some cases the inlet valve is with advantage closed later than at this point.

The contents of the cylinder at this moment comprise a gaseous mixture of air and petrol vapour, the vapour having been formed by a jet of petrol set in action by the carburettor. The air entering the cylinder has to pass through the spray of the jet and in this manner it carried away the atomized petrol.

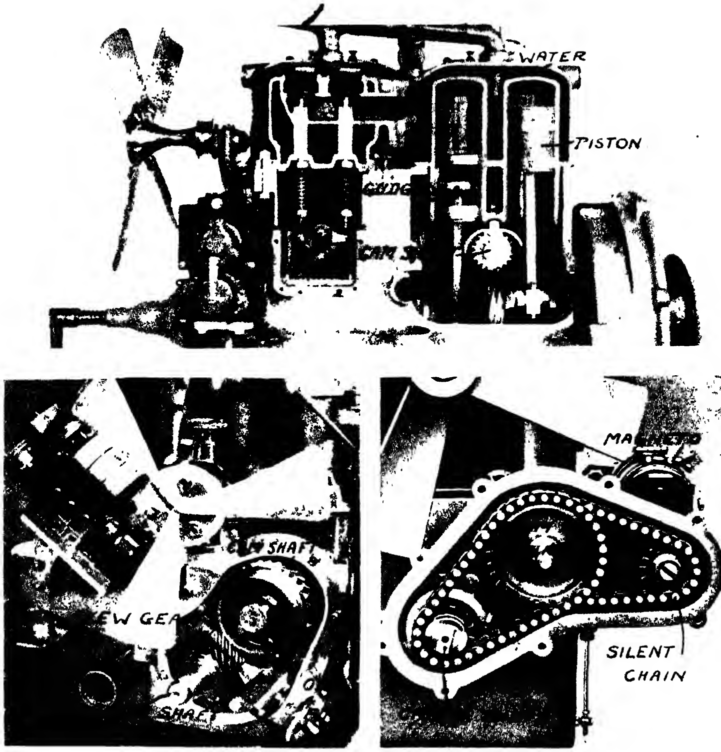
The spray of the jet is itself maintained by the suction effect of the air rushing along the induction pipe on its way to the cylinder. The state of the mixture inside the cylinder at the end of the

suction stroke is such that its pressure is more or less the same as that of the atmosphere, and if ignited it would burn but would not explode. Extreme rapidity of burning is the fundamental difference between explosion and mere combustion.

As soon as the crank-shaft has made its half-revolution, the continuation of the rotation of the crank causes the piston to reascend to its original position adjacent to the cylinder-head. This stroke is called the compression stroke, because during this period the charge of mixture imprisoned in the cylinder is compressed from its original volume, which more or less filled the cylinder, into a volume that is perhaps about a quarter as great, or even less.

It now occupies the clearance space between the piston and the cylinder-head and the additional space provided by the small chambers containing the valves. Thus compressed to a pressure of, say, 70 lbs. per square inch, as compared with the pressure of the atmosphere, which is about 15 lbs. per square inch (these figures are only by way of example), the charge has been rendered highly explosive, that is to say, if ignited it will burn unusually rapidly and give rise to the high pressure that is always associated with the phenomenon of explosion.

The sudden increase in pressure is due to the very rapid heating of the imprisoned gas by the



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ENGINE INTERIORS

The upper view illustrates an unusual method of driving the cam-shaft. On the Spyker engine, the cam-shafts are placed transversely between the cylinders and are driven by skew gearing. Ordinarily the cam-shaft lies parallel to the crank-shaft and is driven either by ordinary spur gearing or by a silent chain. An example of the latter is shown in one of the central illustrations. Generally, the magneto spindle is driven in the same way as the cam-shaft, but occasionally it is placed transversely and is driven by skew gearing. An ingenious design in which the magneto-shaft was placed obliquely so that an extension of the driving shaft could operate the oil pump, is illustrated in the photograph of the Sheffield Simplex engine on the left. In this case the cam-shaft was also driven by the same skew gearing in order to obtain its advantages in respect to silence.

combustion of the gas itself, which combustion in the case of petrol mixture is accompanied by the generation of a great quantity of heat. Heat is the universal source of power, and it is because a very small quantity of petrol contains such a very large quantity of latent heat that it is such a serviceable fuel in these small engines.

The heat liberated by the combustion of the gas is so great that much of it passes into the metal of the engine, which has to be artificially cooled, generally by the circulation of water through jackets surrounding the cylinders, in order to prevent dangerous overheating such as might distort the metal or otherwise interfere with the proper operation of the different parts. The heat thus absorbed by the cooling water and the metal is absolutely wasted.

The real useful work done by the heat of explosion is that resulting in the expansion of the gas and the driving down of the piston to the bottom of the stroke. This movement turns the crank-shaft through a half-revolution against the resistance of the work that it has to do, and also imparts to the fly-wheel a quantity of motion (momentum) sufficient to enable the energy therein stored up to carry on the appointed work of the engine during the next three idle strokes of the piston.

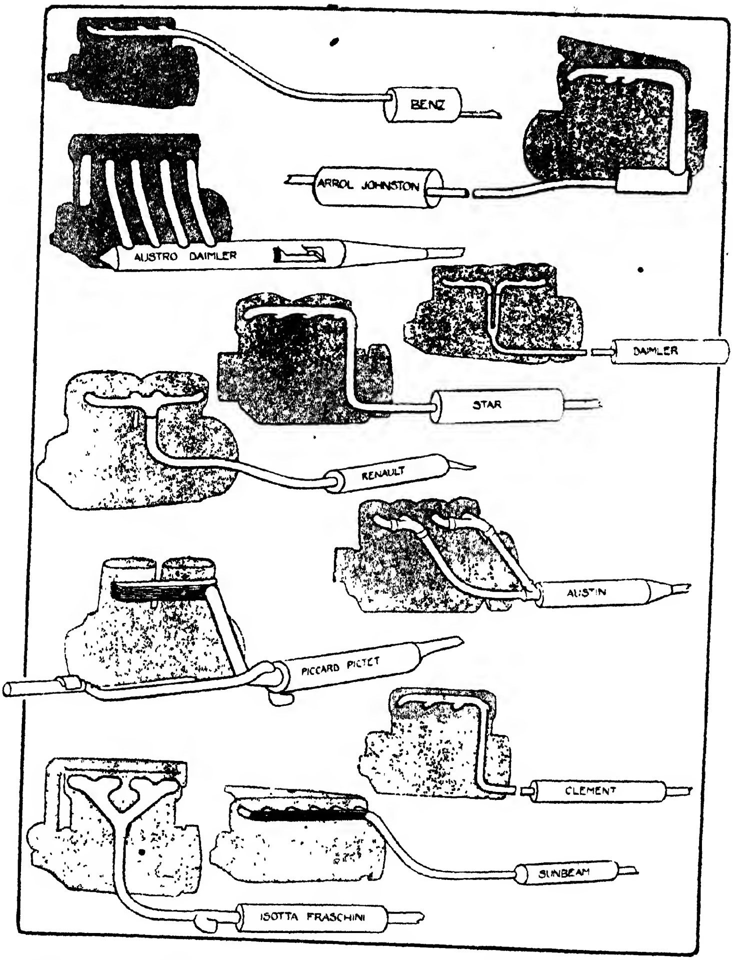
The stroke of the piston just described is called the firing stroke or the working stroke ; it is the

only period in the cycle during which energy is actually generated in the engine. The interval between two working strokes, that is to say, the major period comprising one and a half revolutions, is given up to the discharge of the burned gases and to the preparation of a new charge. During this major period the work is carried on by the energy stored in the fly-wheel.

If the engine has more than one cylinder, and it has been explained that most modern engines have not less than four, the cranks on the crank-shaft are set at an angle to one another, so that the working strokes in each cylinder follow in regular sequence and thereby maintain greater uniformity of impulse. This minimizes the necessity for a heavy fly-wheel.

In a 4-cylinder engine, the four working strokes occupy a period corresponding to the entire period of the cycle of operations for one cylinder. Thus, every idle stroke of the piston in every cylinder is compensated for by a working stroke of one piston in some other cylinder.

At first sight, this would appear to obviate the necessity for a fly-wheel altogether, but owing to the fact that the pistons have no crank leverage at the end of the stroke, the connecting-rod and the crank being in a straight line at these points, a fly-wheel is necessary in order to carry the pistons over their "dead centres," as these positions are called. In 6-cylinder engines, and other engines



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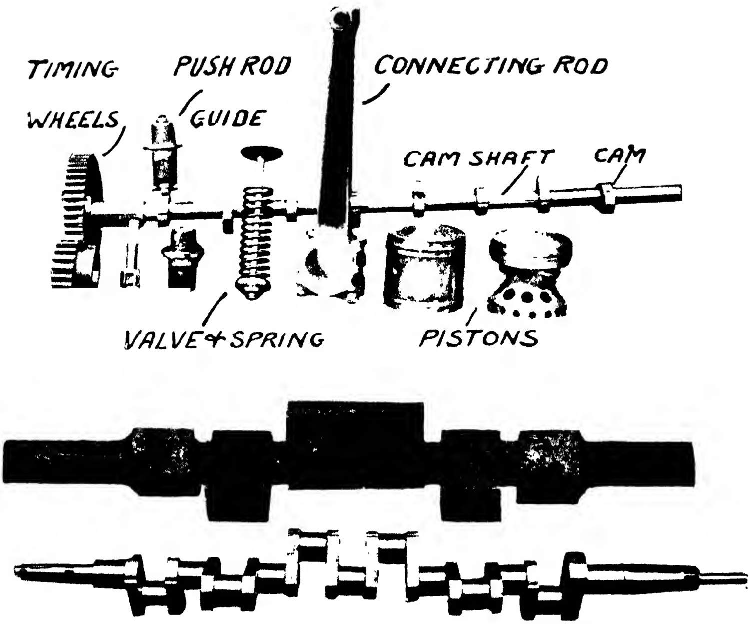
Diagrammatic sketches illustrating various systems of pipe work, by which the exhaust gases are led to the carburettor.

in which there are more than four impulses during a cycle, the torque on the crank-shaft never becomes zero, and the fly-wheels employed may be of very small size.

After the firing stroke is finished, the gas, which may or may not have ceased to burn, has to be expelled from the cylinder in order to make room for another charge. The return stroke of the piston is, in the 4-stroke cycle, therefore devoted exclusively to scavenging. Another valve, commonly adjacent to the inlet valve, is mechanically opened, and the ascending piston drives out the products of combustion into the exhaust-pipe. This latter commonly communicates with a box containing a number of baffle-plates that silence the noise otherwise caused by the sudden liberation of the hot gas into the atmosphere. This up-stroke of the piston is called the exhaust stroke, and it is immediately followed by the suction stroke with which the 4-stroke cycle commences, as already described.

Such is, in brief, an outline of the principles of the 4-stroke cycle of operations on which most petrol engines work; it remains to refer, also briefly, to the functions performed by some of the supplementary mechanism.

The valves of most petrol engines are of the mushroom type. This, as the name implies, consists of a stem surmounted by a disc-head, the whole piece being generally machined from



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SOME OF THE COMPONENT PARTS OF AN ENGINE

The upper group of Vauxhall parts includes the cam-shaft, which operates the valves by means of push rods that make contact with the cams through rollers. The gears for driving the cam shaft are commonly known as the timing wheels. Two pistons are shown, one being a special design for use on racing-car engines. In the lower view, a six-cylinder Daimler crank shaft is shown as a rough forging and as a finished article. Sometimes a crank shaft is roughly stamped to shape between dies that squeeze the metal whilst it is hot.

solid steel. The stem is carried in a guide and the head normally closes an orifice as a plug might be used to seal a pipe. The orifice in question is sometimes situated directly in the top of the cylinder, and sometimes in a small chamber jutting out from the side of the cylinder-head. In any case, it serves as a communication between the interior of the cylinder and the inlet-pipe or exhaust-pipe as the case may be.

The inlet and exhaust valves are commonly interchangeable. The valve-stems move up and down in their guides through the agency of tappet rods, which are steel rods interposed between the valve-stem and the cam-shaft.

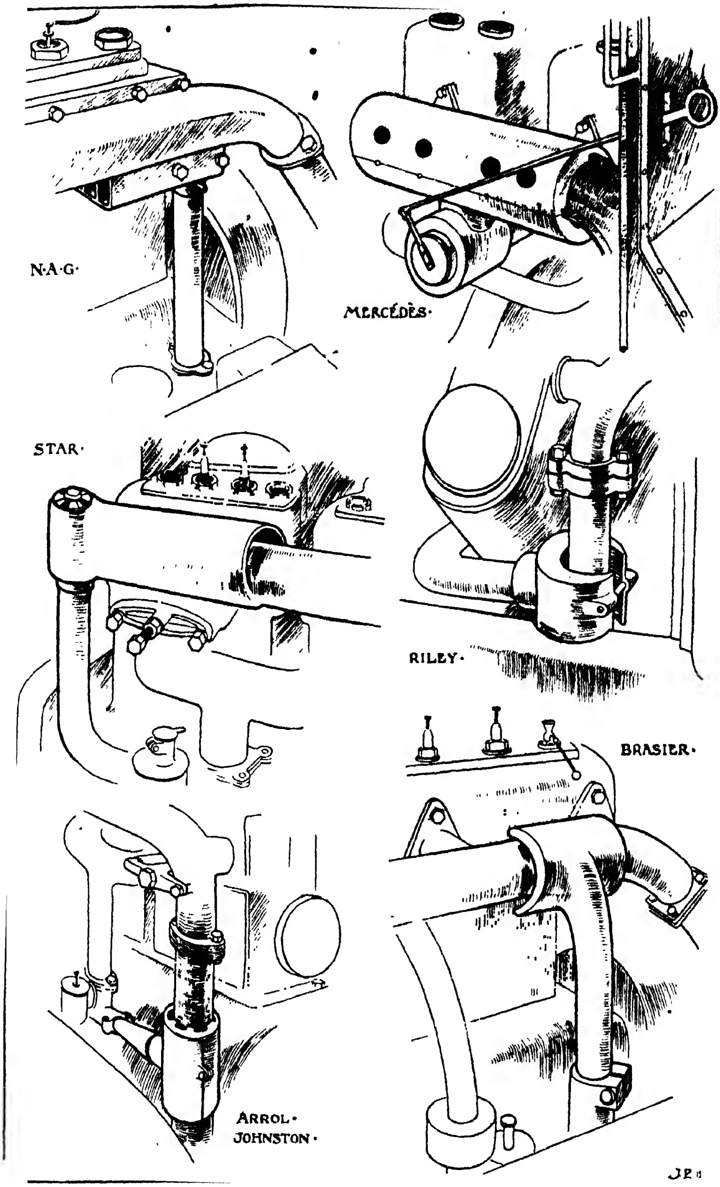
The cam-shaft is a shaft lying parallel with the crank-shaft, and it is gear-driven by the crank-shaft at half its speed. In many cases a chain replaces the direct intermeshing of the gears, in order to give more silent operation. The cams are shaped projections protruding from the surface of the shaft at intervals, and they are usually machined from the solid steel. Their purpose is to raise the valves off their seats, through the mechanism described, at predetermined instants throughout the cycle. Usually, the tappet rods have rollers fitted to their lower ends in order that the cams may push them upwards with less friction.

A cam, such as is used for this purpose, is capable of operating only in one direction, that is to say, it is only capable of lifting the valve off

its seat; the valve is replaced on its seat by the action of a spring, one end of which is coupled up to the valve-stem, while the other end abuts against the cylinder-casting.

In order to obtain the explosion that commences the working stroke, it is necessary to ignite the gas artificially. On all modern engines, electricity is employed for this purpose. In some cases, a battery of accumulators supplies the current, but more often magnetos are employed for this purpose. The magneto is a specialized electrical machine, identical in its action with the medical shocking-coil; it is similar in principle, although on an infinitely smaller scale, to the dynamos and alternators that supply electric light and power commercially. The electric impulses of the magneto are distributed to the ignition-plugs, of which there is one in each cylinder, in the proper sequence to correspond with the firing strokes, and when the impulse is delivered to the plug a small but very hot electric spark jumps between the points of the plug, which project within the cylinder.

This spark ignites the gas and gives rise to the explosion. The plug itself comprises a steel wire embedded in a piece of porcelain that is carried in a steel tube provided with a screw thread, so that it can be fixed in a hole in the cylinder. One end of the insulated steel wire of the plug projects a little way into the cylinder, and it is commonly



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Sketches illustrating various fittings that are used on engines in order to obtain a supply of hot air for the carburettor from the environment of the exhaust-pipe.

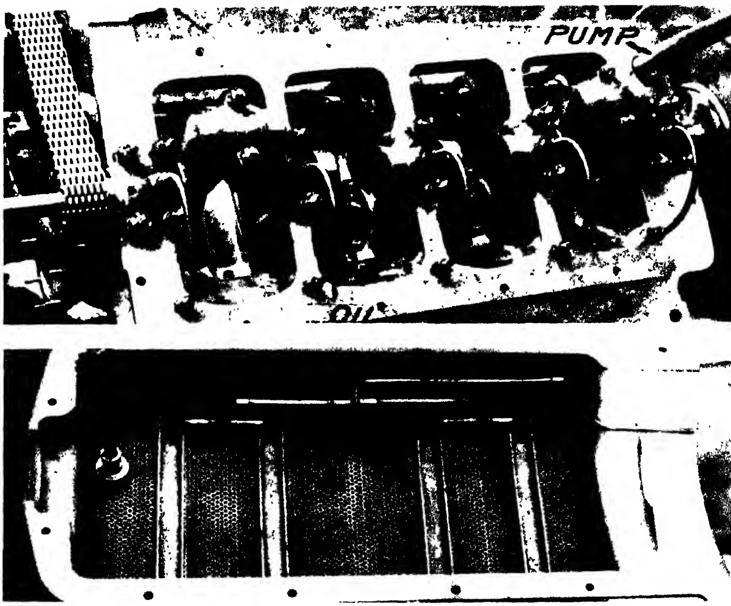
turned over so that its point comes within a few thousandths of an inch or so of the steel body of the plug.

The space between these points is called the "gap," and it is here that the spark takes place. The spark itself is a phenomenon associated with the disruptive discharge of electricity in the medium of a gas, an example of which on a more magnificent scale is demonstrated by lightning.

Ordinarily, only one wire is led from the magneto to each ignition-plug, but the current returns to the magneto through the metal body of the plug, the cylinder-casting and the framework generally. It is because the return path of the current is thus "earthed" that it is so necessary carefully to insulate the other wires from contact with any metal part of the car. Air, rubber, and porcelain are among the best insulators.

Reference has already been made to the action of the carburettor, but a somewhat more detailed description of its operation may be helpful. Most modern carburettors are of the float-feed spray-jet type, and their essential purpose is to discharge a spray of petrol from a very fine bore jet whenever the pressure of the atmosphere in the vicinity of the jet is reduced below its normal atmospheric value.

If the jet were to discharge petrol continuously the fuel would obviously be wasted. A carburettor is therefore adjusted so that although the petrol



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Lubrication

Various methods of lubricating the crank-shaft of an engine are in vogue, and the above photographs show two systems that lend themselves to illustration. Some methods cannot very well be photographed. In the upper view, oil is forced by a pump through pipes to the main bearings, each bearing having its own separate pipe which communicates with a common service pipe supplied from the pump. The engine has been turned on its side to expose the crank shaft in position, and the base chamber has been removed. In this engine, a Vauxhall, the crank-shaft is supported by bearing caps from the upper part of the engine base. In some cases the lower part of the engine base supports the crank-shaft. In the lower view, oil is delivered by a pump to a series of troughs, into which little scoops fastened to the lower ends of the connecting rods dip at each revolution. These scoops communicate with the bearings of the connecting rod big-ends on the crank-shaft. In some cases the supporting bearings and the big-end bearings are independently lubricated by different methods, but in other cases the crank-shaft is drilled with oil-ways, so that the oil can be forced to all the bearings through the interior of the crank-shaft. Originally, engines used to be lubricated by maintaining oil in the base chamber at such a level that the connecting rods would splash into it as the crank-shaft revolved. An objection to this system is that it does not lend itself readily to regulation, and surplus lubricant tends to promote a smoky exhaust by getting past the pistons into the combustion chamber, where it is partially burned. The residue deposits as carbon on the cylinder head and on the ignition plugs, thus tending to promote pre-ignition and missfiring. The piston and the gudgeon pin by which the connecting rod is hinged to the piston, are, as a rule, lubricated by the oil that, exuding from the big-ends of the connecting rod, is thrown in all directions as the crank-shaft revolves. In some cases, a pipe is led up to the connecting rod from the big-end to the gudgeon pin, in order that the latter may be brought within the direct scheme of lubrication. In this case, the gudgeon pin is sometimes drilled so that oil can pass through it on to the cylinder walls.

stands level with the top of the jet, and may even form a little bead at the orifice, it does not produce a spray until the pressure in the induction-pipe is reduced by the suction of the engine.

The inrush of air itself is caused, as already explained, by the suction effect resulting from the descent of the piston in the cylinder. As the petrol sprays from the jet it is carried away by the air, with which it forms what is to all intents and purposes a gas.

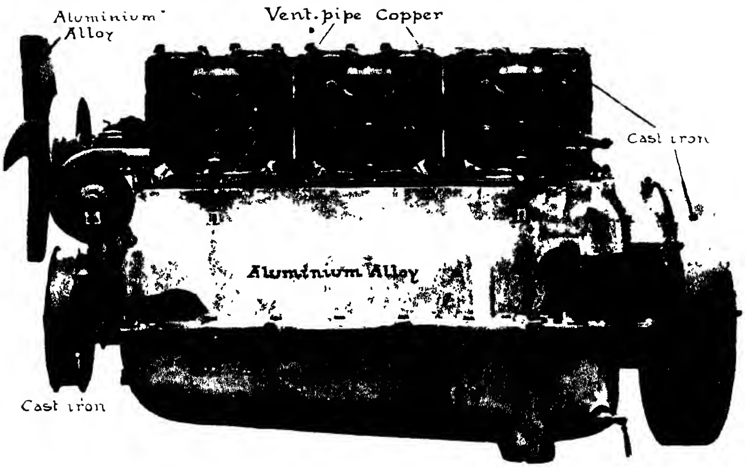
In order to maintain the petrol at its proper level in the jet, so that the operation of the jet may be sufficiently sensitive to respond automatically to the movement of the air in the induction-pipe, a regulating device, known as the float-feed chamber, is employed. The float-feed chamber contains a hollow metal drum that is buoyant in petrol. Resting on the top of the drum or float are, usually, a pair of small levers controlling the action of a pointed spindle, which acts as a needle valve regulating the admission of petrol from the main tank into the float-feed chamber. By this means, the level of the petrol in the float-feed chamber is always kept constant, and as the jet is in direct communication therewith, the level in the jet is likewise always constant.

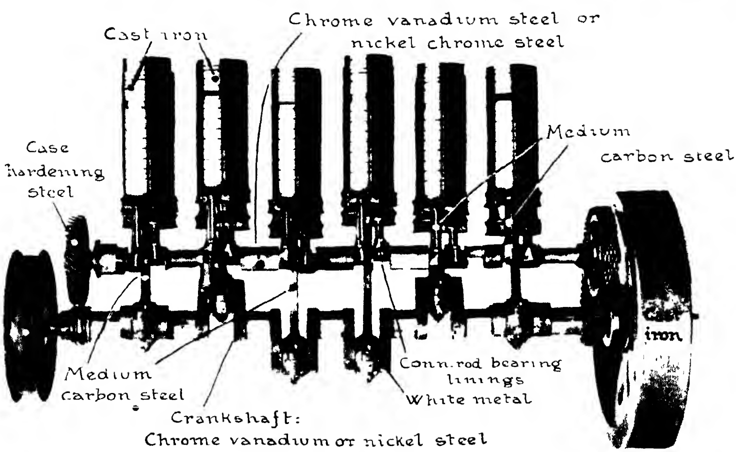
When starting up the engine by hand, it is common practice to "flood" the carburettor temporarily by raising the needle valve. This

latter commonly projects through the lid of the float-chamber for this purpose. Such action causes an overflow of petrol from the jet and results in the volatilization of a quantity of petrol in the induction-pipe. An explosive gas is thus more readily drawn into the cylinders when the engine is cranked by hand. Once the engine is in operation, its relatively high speed, as compared with the rate at which the crank-shaft can be turned by hand, induces all the suction that is required to create an effective spray from the jet.

There is one other point associated with the operation of multicylinder engines to which reference must be made, and that is the fact that the sequence in which the cylinders fire is not the same as that in which they are situated in relationship to one another. Thus, for example, the crank-shaft of a four-cylinder vertical engine has its cranks set at 180 degrees to one another; that is to say, they all lie in the same plane, and those at each end are opposite to those in the centre, which are adjacent to one another. If, therefore, we assume that the cylinders are numbered 1, 2, 3, 4, in the sequence of their arrangement on the crank-chamber, their firing order will be 1, 2, 4, 3, or 1, 3, 4, 2, according to the choice of the designer.

Some stationary vertical engines are so constructed that the plane of the cylinders is dis-





THE DAIMLER ENGINE

In the Daimler engines, the admission and exhaust of the gas is controlled by cylindrical members called sleeves, which are situated inside the cylinders and surround the piston. The piston works up and down within the innermost sleeve. There are two sleeves in each cylinder, the sleeves being, of course, concentric. Slots are cut in the sleeves, and the up-and-down motion brings the appropriate slots opposite to each other and also opposite to the proper orifice in the cylinder wall when the gas has to be admitted or ejected. The upper photograph shows a six-cylinder Daimler engine complete, except for its external pipe work, and underneath it is a complete set of sleeve valves with their operating mechanism. The crank-shaft and connecting rods are also shown. In order to illustrate the many different materials used in motor-car construction, the nature of the various parts is indicated.

placed to one side of the plane of the crank-shaft. This displacement is made in the direction of rotation. Its immediate effect is to retard the moment at which the piston reaches the top of its stroke until after the crank has arrived at its vertical dead centre. In consequence of this, the obliquity of the connecting-rod is diminished throughout the entire duration of the firing stroke, and the lateral pressure and consequent friction between the piston and the cylinder-wall during that period is thereby reduced. It is, of course, during the firing stroke that such lateral pressure is most pronounced, because the forces in action then have their highest values.

It necessarily follows that if the connecting-rod is less oblique during the firing stroke and also, of course, the suction stroke, it must be relatively more oblique during the exhaust stroke and compression stroke.

A consequence of this *desaxé* principle that is not so obvious at first sight, is that the actual length of stroke traversed by the piston in the cylinder is greater than that in the orthodox engine having the same crank radius. Ordinarily, of course, the stroke of the piston is equal to twice the throw of the crank, but in the *desaxé* engine this dimension is exceeded by an appreciable amount and, in consequence, the effective volume of the cylinder is thereby increased as compared

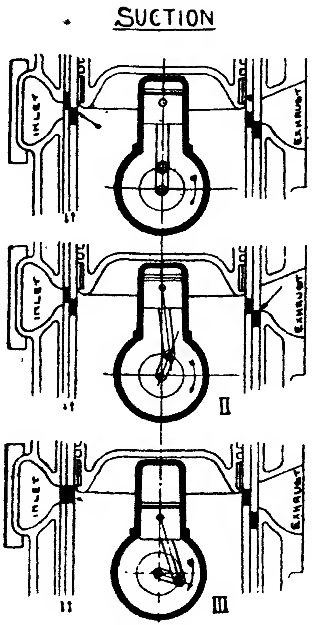
with an ordinary engine having the same crank-shaft.

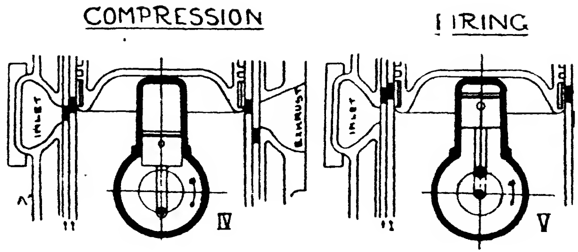
A special form of engine that is now as familiar as the more orthodox type is that introduced by the Daimler Company in September, 1908. For some years this firm had been experimenting with a motor invented by Mr. C. Y. Knight, of Chicago, and as the result of their tests they decided to adopt it as their sole standard model. It was a remarkably bold policy, perhaps the boldest that has ever occurred in the industry of automobile engineering, but it was justified by the subsequent commercial success of the motor in question.

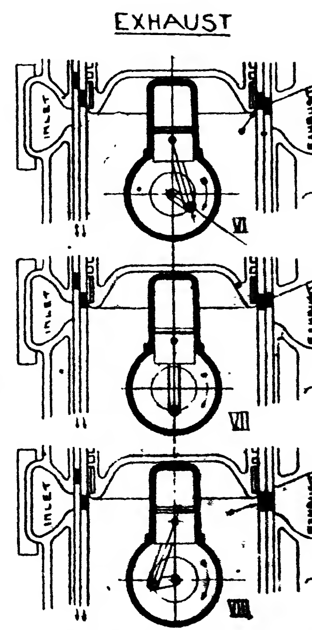
This Daimler engine does not employ valves of the type just described, but uses a pair of concentric tubes or sleeves that slide up and down inside the cylinder. These sleeves are a close fit inside the cylinder, and they form, as it were, a lining to the cylinder. The piston works inside the inner sleeve, and is not, therefore, in direct contact with the cylinder-wall.

The motion of the sleeves is controlled by links from an eccentric shaft that occupies a similar position, and is similarly driven to an ordinary cam-shaft.

In the sleeves are slots that move across openings in the cylinder-walls, through which the gases enter and escape from the cylinder. As there are two sleeves, it is necessary for the slots in each to correspond with each other as well as with the







The Daimler Engine.

The diagrams show eight different positions of the sliding sleeves throughout the working cycle of operations performed by the engine in the course of two revolutions. In the centre of each diagram is a little sketch showing on a smaller scale the position of the piston in the cylinder. It is important to notice that the ports in the sliding sleeves are shown black. They are, therefore, open in respect to one another when the black patches overlap. The numerical order of the diagrams represents the sequence in which the various positions occur, and, for greater lucidity, the diagrams have been arranged in vertical columns to represent points in the four principal operations—suction, compression, firing, and exhaust. It should be noted, however, that while Diagram II occurs in the suction stroke, it also represents the closing of the exhaust port. Arrows below each sleeve indicate the direction of their motion. The points illustrated by the diagrams are as follows:—

I. Beginning of suction stroke, inlet port just opening between sleeves. The exhaust ports are still open.

II. Exhaust ports closing between outer sleeve and cylinder wall.

III. Inlet ports full open between both sleeves and cylinder.

IV. Compression stroke commencing with inlet ports still open.

V. Firing stroke commencing with all ports closed.

VI. Exhaust port just opening between inner sleeve and cylinder-head as piston approaches end of firing stroke.

VII. Exhaust ports well open when piston has reached its lower dead centre.

VIII. Exhaust ports full open before piston has travelled half-way up on its avenging stroke.

port in the cylinder-wall before a through communication is established. The principle of action is thus somewhat like that of a number lock for which there is only one setting that releases the bolt.

Primarily, the object attained by the Daimler engine is silence in conjunction with high power. Fundamentally, parts that slide across one another are potentially more silent than a valve that strikes against its seating. In general, the development of high power in a poppet-valve engine tends to make for a noisy valve motion, although it must be admitted that such engines have been improved immensely in this particular of late.

In the Daimler engine the sleeves are positively controlled by their operating links in both directions, whereas in the poppet-valve engine it is a spring that closes the valve.

There are many other interesting and important points of comparison between the two types; but their purely technical character is somewhat outside the scope of this book.

At a more recent date, the Argyll factory also adopted a sleeve-valve engine, which, however, differs from the Daimler engine in having only one sleeve in each cylinder.

The motion of this sleeve, instead of being straight up and down, is elliptical; that is to say, it performs a partial rotation in addition to a

longitudinal motion inside the cylinder. It also has justified the maker's enterprise by its success, and particularly did it advance itself in public esteem by a very severe trial that was carried out at Brooklands during 1913.

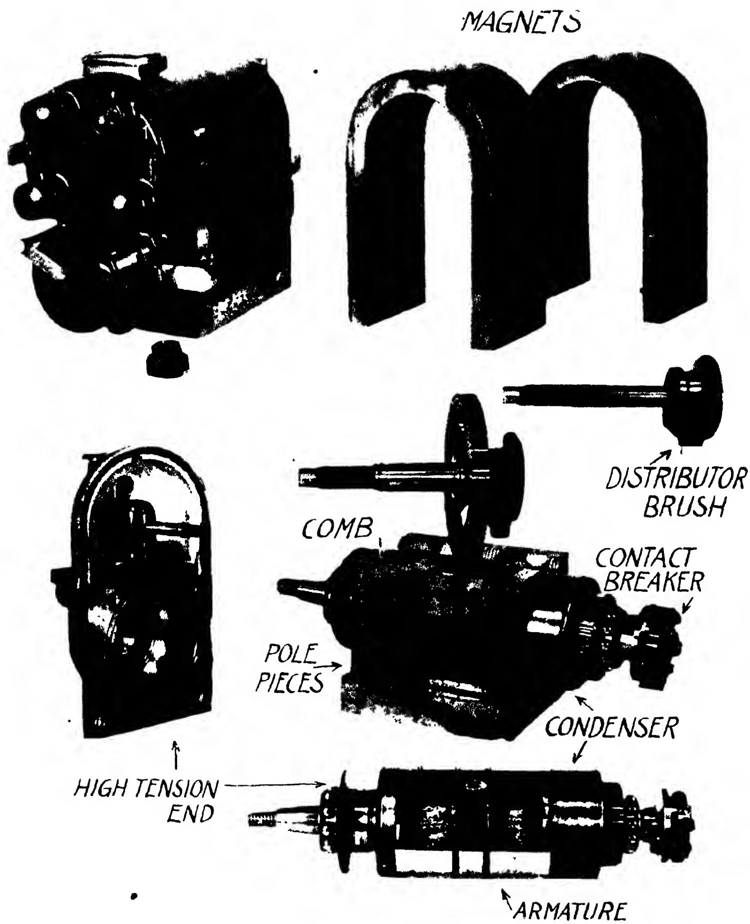
CHAPTER X

THE MAGNETO

THOSE who stop for a moment to think of the universal employment of the high-tension magneto on modern cars, and who realize what sort of mechanism (I was almost saying box of tricks) it is that has won such phenomenal prestige under the strenuous conditions of present-day motoring, should have small difficulty in acknowledging the credit due to those who have accomplished such a significant performance in so short a time.

It may be unknown to some that magnetos were used at a very early date indeed in the history of the development of the small high-speed internal-combustion engine. The fact that low-tension magneto-electric ignition was ousted by the hot-tube system—the idiosyncrasies of which are among the treasured experiences of those who drove cars in the very early days—serves only to illustrate the seriousness of the difficulties that have so successfully been overcome.

Greater attention to mechanical detail and to the choice of material, subsequently reinstated the low-tension magneto as a rival to the hot-tube,



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THE CONSTRUCTION OF A HIGH-TENSION MAGNETO

The machine actually employed as an example is the Bosch Z U 4 model. The magnets are of hard special steel, and retain their magnetism indefinitely. The rotation of the armature in the magnetism between the pole pieces generates impulses of electricity in the wire that is coiled on the iron core of the armature. There are two such coils, and the circuit of one of them is switched open periodically by the contact breaker. The opening of the circuit induces an electro-magnetic reaction in the other coil, which gives rise to a very high voltage at the high-tension end of the machine. This high voltage is distributed to the ignition plugs and produces the spark that ignites the charge in the cylinders. The condenser facilitates the reaction between the two coils. The combed pole piece facilitates starting with the ignition lever retarded.

and when earlier high-tension battery systems and the earlier high-tension magnetos first appeared, their initial imperfections prolonged its lease of life sufficiently to permit of partisan opinion as to relative merits, which found its usual vent in the correspondence columns of the technical Press.

Of the causes that led to this sequence of changes, one stands out above others as the real criterion of merit in ignition systems. It is their relatively greater ability to synchronize the spark in the cylinders of a multicylinder engine.

The term synchronized ignition is familiar to all motorists: it means that the spark occurs at precisely the same relative moment in each cylinder. That is to say, if the spark happens in one cylinder when the piston is an eighth of an inch from the top of the stroke, then it occurs when the pistons of the other cylinders are precisely at the same place.

To ensure this synchronism with low-tension ignition was difficult, because the igniters and their tappets would wear unequally and, therefore, needed much careful adjustment. Similarly, it was also difficult to adjust the tremblers of a multicoil battery system so as to give a truly synchronized spark.

The introduction of a revolving high-tension switch, in the form of a distributor, for use with a single coil, much facilitated the synchronizing of

battery ignition, but the high-tension magneto, to which the distributor was equally applicable, had the additional advantage of making its own electricity, whereas a battery of accumulators was merely a storage place that was far too apt to run dry at inconvenient places to be fully adapted to the needs of the touring motorist.

At first, the high-tension magneto was regarded as a very questionable advantage, for the duty of turning out as many as a million sparks a day was often beyond the powers of a mechanism having the internal delicacy of clockwork, yet operating under conditions of shock and vibration that would be a severe trial to the most robust of engineering structures.

And when I recall the nature of some of the early machines that I used to dissect, the wonder is that they would last for an hour while doing such work. Some of the very early magnetos—and there was an extraordinary crop of varied types during the first few years of their budding popularity—failed through lack of the minor refinements that are so essential to the successful operation of such mechanisms.

The magneto, I have said, won the day against the battery because it could make its own electricity, while the high-tension system ousted low-tension ignition for the reason that it could more easily be synchronized, and also because it avoided the obvious objections that may be levelled against

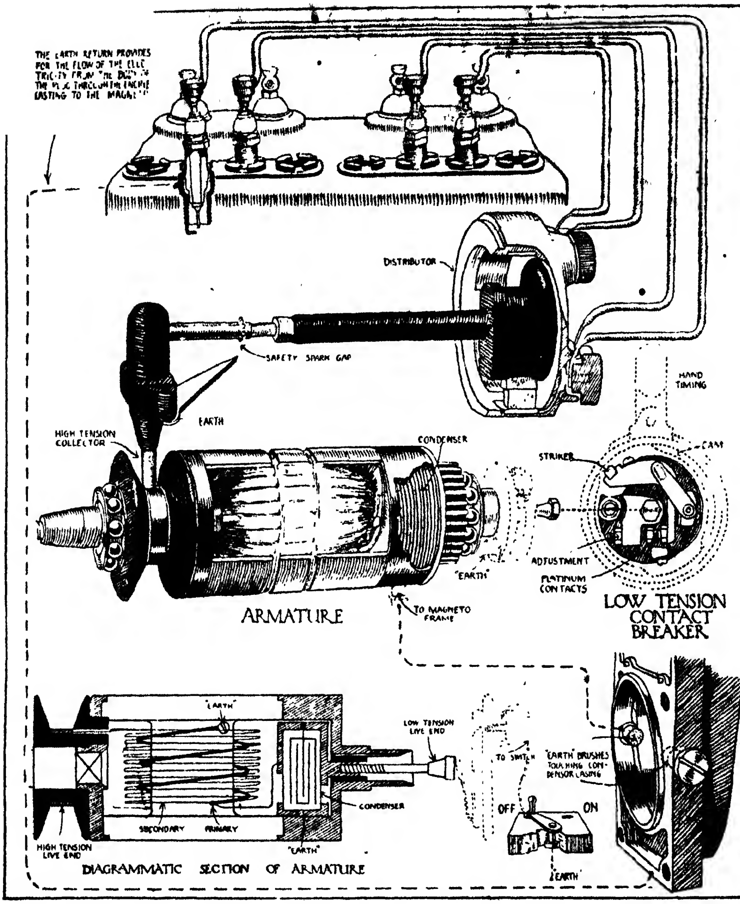

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Diagram of a typical high-tension ignition system, illustrating the complete circuit through which the electricity flows from the magneto to the ignition-plugs, and back again to the magneto. The return path from the ignition-plug is provided by the metal parts of the engine, and is commonly called an "earth" return. Another illustration shows the component parts of the magneto, and the inscription thereunder describes their action. The above drawing shows how the high-tension electricity is collected from the armature, and is distributed to the ignition-plugs in their proper firing sequence. Should one of the ignition-plug circuits be out of action, so that the electricity cannot flow through the plug, the impulse discharges as a spark at the safety spark-gap. The drawing also illustrates diagrammatically the two coils on the armature and the connections of the contact-breaker and the switch.

the insertion of moving members through the walls of cylinders that it is essential to keep gas-tight.

The uninitiated may well ask what are the essential differences between these different forms of electricity that come, one sort from batteries, another sort from magnetos; and between one kind that is called low-tension and another high-tension. It is with the object of answering such queries in a way suited to those who know nothing of the theory of the subject that I proceed to make a few further elementary remarks.

In so far as the spark itself is concerned, it is an example of high incandescence due to the heating effect of the flow of electricity across the gap. Its ability to fire the charge is due to the incandescence and not directly to the electricity. So, too, is the light of an electric lamp due to the incandescence of its filament rather than to the fact that electricity is the cause thereof. When much electricity is forced to pass in a fine wire, the wire gets over-hot, glows, and finally fuses if it is exposed to the atmosphere, but remains in a state of brilliant incandescence if it is enclosed in a vacuum globe. An arc light owes its great illuminating power to the incandescence of the fine dust that discharges from the carbon; lightning is another form in which the passage of electricity produces incandescence. There are other phenomena that may be readily recalled in which electricity is

harnessed in the service of man for the generation of heat.

Electricity in respect to ignition, therefore, is only a means to an end; the magneto and the battery are merely different devices by which the means is rendered available on a car.

Electricity itself exists passively in nature, but several processes for bringing it into action are known to science. I propose referring to three of them.

If a stick of sealing-wax is rubbed with a piece of flannel, it will become charged with electricity on its surface, and will act as if it were a magnet in the way that it will attract towards itself tiny pieces of paper.

The behaviour of water is often used as an analogy for the action of electricity in order to assist the mind in obtaining a picture of the conditions. In the above experiment, the surface of the sealing-wax may thus be supposed to be wet.

Another means of producing electricity is to attach the ends of a wire, which is to form the electric circuit, to certain materials, zinc and carbon, for instance, and immerse them in a suitable medium, such as a solution of sal-ammoniac in water. In this we have the familiar wet-jar cell of the household electric-bell circuit. Another form of much the same thing is the popular dry cell that you may purchase at any ironmonger's.

Both need replacing with new materials when

they are run down. By a change of materials and modification of design, however, a battery can be made that may be restored when exhausted by causing chemical changes in the material by the action of electricity itself. Thus, by reversing the flow of the electric current, the battery may be recharged; obviously, it is necessary to subject the battery to a voltage superior to its own.

Whether or no the materials are replaced or recharged is of small consequence compared with the main fact that they last only a short time under constant use, and so the system, as a whole, tends to be inconvenient to the motorist.

By the water analogy, they represent the cistern of the isolated country house that is not on the water main. When the cistern is empty it must be refilled by the bucket or by pumping, and either way it is a nuisance.

The third method of generating electricity that I shall mention is one that has revolutionized civilization by its far-reaching consequences.

Everyone is familiar from childhood with the fascination of the steel magnet and its power of attracting other pieces of steel to its extremities. In another form, as a compass, everyone is familiar with its property of pointing always north and south when freely pivoted. A phenomenon less generally known among laymen and less readily demonstrated without special apparatus is the fact that when electricity flows in a wire,

the wire is surrounded by a sheath of magnetism, and that when the wire is coiled, the core of the coil is a magnet so long as the electricity flows in the coil.

Conversely, a coil of wire closed at its ends so as to form a circuit, will have a current of electricity induced in it if a magnet is passed through the core of the coil.

The magnet must fit the core fairly closely to produce the best effect, and, in any case, the electricity will only be produced in the wire while the magnet is moving. In fine, it will merely be an *impulse* of electricity.

The tiny magnetos with which motorists are so familiar are examples of the practical application of this principle in a compact form adapted to a particular purpose. On the same fundamental basis, however, also stand the gigantic alternators of the world's great generating stations, whence electricity representing millions of horse-power is forced ceaselessly to pulsate in the network of copper arteries that serve to convey, as light, heat, and energy, the very life blood of that stupendous creation of our species which we are pleased to call "civilization."

By the water analogy, the magneto is a pump coupled to the inexhaustible well of nature's electricity. Observe closely, however, and bear clearly in mind that it is necessary to work the pump always, whereas the battery works by itself

while it lasts. Electricity, is a phenomenon associated with the manifestation of energy in some form or another; it must be generated by the application of power before it is available for conversion into energy of some other form.

In the sealing-wax experiment, there was the friction; in the battery, the chemical change; in the magneto there is the magnetism. Turn the armature of a magneto by hand, and you will hardly need to be told that not all the resistance you feel is due to imperfection in the modern ball bearing.

How, in a magneto, you may well ask, do the stationary magnets pass through the coil of wire, which you will have recognized is the armature? It is, of course, only the effect of so doing that is produced, but the effect in question is, indeed, the consequence of the rotation of the armature between the magnet poles.

Most motorists of long experience have at one time or another dismembered a magneto, and have noticed that the armature consists in part of a coil of wire wound round an iron core of a section. This iron core is laminated, that is to say, it is built up of numerous thin iron plates that are insulated from one another for the purpose of preventing the promiscuous generation of electric currents in the iron itself. It is also within common knowledge that a piece of iron may temporarily be magnetized by its mere proximity

to a magnet; consequently it may be readily understood that the iron core of the armature will be magnetized by virtue of its position between the pole pieces, although in itself it is not a magnet when removed from its environment.

Again, everyone is acquainted with the distinction between one end of a magnet and the other, which makes the same end of the compass point always to the north. If the north pole of a magnet (the end of the compass that points towards the north) is placed adjacent to a piece of iron, it causes the iron to form a virtual extension to itself. Now if the iron extension were turned round so that the other end were placed adjacent to the north pole of the magnet, it is obvious that the magnetism in the iron would be reversed in the process. Equally is it obvious that between the time when it is magnetized in one direction and then in the other direction, there must be an intermediate position in which to all intents and purposes it is not magnetized at all.

If on this piece of iron a coil of wire is wound, the effect of making the iron alternately a magnet and not a magnet, or rather making it a magnet first with the north pole at one end and then reversing the magnetism so that the north pole is caused to be located at the other end, will obviously be identical with the effect that would be produced by passing a real permanent magnet

through the coil of wire first in one direction and then in the other.

It has been stated above that this action generates electricity in the coil, so then will the process of reversing the magnetism in the iron also generate electricity in the coil of wire. Thus, if the iron core of the armature, on which a coil of wire is wound, is rotated between the poles of a permanent magnet, it becomes magnetized first in one direction and then in the other direction, and so the effect is equivalent to that of passing the magnet through the coil of wire, and electricity continues to be generated in the coil so long as the magneto armature continues to rotate.

But the very nature of the operation makes it apparent that electricity so generated will be of a pulsating kind, just as it is apparent that water delivered from a single-cylinder pump tends also to pulsate. In fact, the situation presented by the magneto is such that the electricity flows first in one direction and then in the other round the circuit. With an ordinary revolving armature magneto and an ordinary horseshoe magnet, there is a reversal of the flow at each half-revolution of the armature.

Since there is a reversal of the flow, it stands to reason that there must be a moment when there is no current at all, and it is equally obvious for the same reason that there must be another instant when the impulse is at a maximum. It

may seem strange, however, that the maximum position should be when the armature core reverses its magnetism and not when it is at the height of its magnetic intensity. From the preceding remarks it will be very clear, therefore, that the maximum position of the armature occurs when the armature core stands perpendicular between the pole pieces and not when it is lying in line with the pole pieces.

This truly vertical position is a theoretical maximum position only; owing to the tendency of the rotating armature to, so to speak, drag the magnetism round with it as if the magnetism were some sticky fluid that adhered to the armature core, the real maximum position occurs when the armature has rotated somewhat further than the vertical position. Moreover, this displacement, due to the magnetic drag, varies with speed somewhat, and so the maximum position is not exactly a fixed point.

It is a matter of common knowledge to motorists who look after their own cars that the spark is caused to occur at the ignition-plug by the separation of the platinum points of the contact-breaker. Normally, the platinum points are in contact with each other, and the construction of the magneto is such that these platinum points virtually form the extremities of the coil of wire on the armature core to which allusion has already been made. Their sudden separation acts

as a switch in opening a circuit that was formerly closed, and the result is a spark at the ignition-plug. The occurrence of the spark is due to causes that will presently be explained. For the moment, I merely wish to draw attention to the fact that the strongest spark will naturally be given by separating the contacts when the armature is in its maximum position, which maximum position, as I have already pointed out, has a habit of changing its place with the speed.

The significance of the above remarks will better be realized when it is fully appreciated that the direction in which the maximum position tends to shift with increasing speed is opposite to the direction in which the timing-lever is moved to advance the ignition. Consequently, if the magneto is set so as to make the maximum position at high speeds coincide with the operation of the contact-breaker, there will be great difficulty in obtaining any spark at all when the lever is retarded for slow speeds and for starting. Alternatively, if the magneto is set so as to give the best spark at very slow speeds, the high-speed sparking may tend to be sluggish. The high speed in itself, however, increases the voltage, and so tends to mitigate this drawback. It is, in fact, on the rise in voltage with increasing speed that the fixed ignition systems depend for their automatic advance, which is, in itself, merely a tendency to reduce the lag in the system at all

points, owing to the superior effect of a higher pressure.

I have drawn attention to the above connection between the variation in the maximum position and the timing, because it is in the manner in which modern magnetos to a great extent surmount this difficulty that one of the most notable improvements in design has been made. In the ZU4 Bosch, for instance, one edge of each pole piece is fashioned like a comb. The object of this formation is to distribute the magnetism in such a way as will tend to give a range of maximum positions having sensibly uniform values, instead of only one well-defined point of great intensity. With an ordinary pole piece there is a tendency for the magnetism to crowd into the centre and hang on to the very last moment, when the reversal takes place with great suddenness. The comb edge tends to prevent this, and provided the magnets are powerful enough in the first instance—which the manufacturers may be trusted to take good care is the case—it is a distinct advantage to have this wide range of sufficiently strong maxima instead of merely one intensely strong maximum. Fixed ignition magnetos are not provided with these comb pole pieces.

From the chauffeur's point of view, there is no need to be concerned about the exact relative position of armature and pole piece that gives the best maximum at any particular speed. The

magneto manufacturers mount the contact-breaker itself in a fixed position on the armature spindle, and the only thing that whosoever may be setting a magneto to an engine can ensure is that the range of his timing-lever covers the range of advance and retard as it is, or should be, set out on the fly-wheel marking. If the fly-wheel is not marked for the timing, then it is safe to set the magneto so that very nearly its full retard corresponds to the piston being on its upper dead centre. On motor-cycles that have only one gear ratio and are used for touring, it is good practice to allow one-third of the range of the timing-lever for retard beyond the dead centre; two-thirds of the range is thus available for advance.

It is now necessary to consider the general principles underlying the generation of the high-tension spark; for thus far I have dealt only with the method by which electricity is generated in the armature coil. There are two coils of wire on the armature of a high-tension magneto. One of them is composed of comparatively stout wire, and is called the primary winding; it is this coil that we have been considering hitherto.

The other coil of wire on the armature consists of a great many turns of very fine wire: it is called the secondary winding. In this secondary winding is generated the high-tension electricity that creates the spark. In principle, both ends

of the secondary winding are connected to the opposite spark-points of an ignition-plug; and, in principle also, the secondary winding may be considered as absolutely distinct and separate from the primary winding. There is an inter-connection on the Bosch magnetos, to which I shall refer presently, but for the moment it will be easier to consider the two circuits as entirely distinct.

One of the most interesting phenomena associated with electricity may be demonstrated by holding two entirely separate coils of wire close together, and causing an alternating current to pulsate in one of them. It will be found that a sympathetic electric pulsation is set up in the adjacent coil, although there is no electrical connection between them whatever. Electric lamps may be lit by this means; for instance, if a flat coil of wire is let into the surface of the table and the lamp bracket carries a corresponding coil of wire in its base, by merely placing the lamp bracket over the other coil, the lamp will light, although the table-cloth may intervene between the two coils.

Although there is no electrical contact between the two circuits, there is an essential link between one system and the other in the presence of the magnetism that is generated by the electricity in the first coil. It has been explained that passing a magnet through a coil causes electricity to be

generated in the coil, and it should seem very reasonable that causing electricity to flow in the coil in the first instance will, conversely, be the means of generating magnetism in its midst. In short, wherever there is electricity there is also a magnetic disturbance, and wherever there is a magnetic disturbance there is also likely to be an electrical disturbance if there is any suitable circuit. This reaction exists even between two parallel straight wires, and you may frequently notice how telegraph wires are crossed in order to neutralize electro-magnetic interference between the lines.

Another interesting point in connection with this phenomenon is that the voltage of the electricity induced in the second coil depends on the relative number of turns between the two coils. If the secondary winding has ten times as many turns as the primary winding it will have ten times the voltage, and so on. On the contrary, it will have one-tenth the amount of current, or rather less, for there will be a loss of energy in the process of transformation, and electrical energy is measured as a product of volts and amperes.

Voltage is the name given to electric pressure, and corresponds in its way to pounds per square inch; the ampère is the unit of electric current, and likewise corresponds in its way to such an expression as gallons per hour in the case of the

flow of water. Both terms are derived from the names of famous pioneer electricians.

From the position of the secondary coil on the armature and the fact that it has many turns of wire, it is apparent that a sympathetic electric pulsation will be induced in the secondary coil by the primary winding, and if at any moment there is an especially violent disturbance of the primary circuit such as is caused by a sudden interruption of the current, the conditions will be transformed to a correspondingly high intensity in the secondary circuit, and the voltage may reach such a magnitude as to cause a miniature display of lightning across a gap that is specially arranged for the purpose. This gap is the gap of the ignition-plug, and the lightning display is the spark.

It will be understood that there is always a tendency for a current to flow across a gap so long as there is any voltage in the secondary coil; and there is voltage in the secondary coil whenever there is voltage in the primary coil. But, under normal conditions, the voltage is insufficient to break down the insulation of the intervening space, for the gas in the cylinder happens to be a very good insulator, particularly when it is under compression. When, however, the primary circuit is interrupted by the contact-breaker, disturbances of an especially acute character take place, the voltage in the secondary coil reaches

an extremely high value, and the insulation of the gap is pierced by a spark.

That there should be a specially severe disturbance on the breaking of the circuit is due to the presence of the condenser. This consists of a bundle of insulated tin-foil, and is usually enclosed, in a brass casing forming an extension of the armature. Formerly it was often carried in a separate casing between the magnets. The bundle of insulated tin-foil usually consists of alternate sheets of tin-foil and mica, forming a packet that is cut to the shape of the receptacle in which it is packed. Alternate sheets of tin-foil are fastened together in a batch at one edge, while the intermediate sheets of tin-foil are similarly connected together on the other side. Thus, the condenser may be likened to the state of two books that have been placed together with their pages interleaved with each other. Or, it may be likened to the process of shuffling a pack of cards where half the pack is forced into the other half so that cards formerly adjacent become separated from each other.

In the electrical circuit, the two sides of the condenser are coupled up permanently across the contact-breaker. The condenser is not in itself a closed electric circuit, for the mica insulates the tin-foil sheets from contact on opposite sides. The condenser does, however, possess electrical capacity—that is to say, it can receive a charge of

electricity on its surface, the combined surface of the numerous sheets of tin-foil being large. The idea of a charged surface has already been presented to the mind by the experiment with the flannel and the sealing-wax, and it is to this order of things that the electrical state of the condenser belongs.

When the contact-breaker has its platinum points separated by the striking of the cam against the bell-crank lever as the armature revolves, the current that is thereby interrupted tends to continue in the form of a spark across the widening gap formed by the receding platinum screw. The mechanism of the low-tension contact-breaker is, in fact, to all intents and purposes the same in principle as that so successfully employed in the form of an igniter to produce a low-tension spark with the earlier forms of magneto ignition.

At the contact-breaker of a high-tension magneto the creation of such a spark would in every way be a drawback. It would burn away the platinum points, and its very existence would imply the continuation of the electric current that it was the object of the separation of the contacts to interrupt.

When a condenser is fitted as a bridge across the gap formed by the separating points of the contact-breaker, however, the capacity of the condenser serves as an alternative place for the electricity, which prefers to charge the condenser rather than

expend itself in maintaining a spark at the contact points. The spark is thus avoided, the life of the contacts is prolonged, and the current is duly interrupted at the precise moment that its cessation is desired.

But the condenser serves a further purpose in that it acts somewhat after the manner of a spring buffer. As its opposite sides are connected together through the armature coil there is a tendency for the condenser to discharge itself as quickly as it becomes charged. Its natural state of electrical equilibrium is neutral, for the fact of its opposite sides being connected together at all times prevents a charged condition being anything more than momentary in duration. The consequence of charging the condenser is, therefore, somewhat equivalent to that of striking a blow at a spring. The spring at first absorbs the blow, but it very speedily strikes back, as witness the example in which the spring happens to be a piece of elastic with a punch-ball attached to it, in the manner that can be seen in any gymnasium.

Moreover, in just the same way that a spring once deflected oscillates to and fro before it comes to rest, so does a condenser set up electrical oscillations of intense rapidity before the disturbance subsides. The whole period covered by the phenomenon is only momentary, but it is, nevertheless, of the greatest consequence, for without a proper condenser it is well-nigh im-

possible to get a proper spark under the usual circumstances.

With these remarks I complete to the best of my ability the explanation of the essential links in the theoretical chain with which the general principles of the operation of the magneto are bound up. There remains only to briefly review the mechanical construction of a modern machine, and to point out one or two extraneous features of interest in connection therewith.*

The magnets themselves are made of a special steel that retains its magnetism throughout a long period of time. Any form of iron can be magnetized, but if the iron is soft it will lose its magnetism very quickly, and particularly so if it is subject to vibration. Hard steel will retain its magnetism more or less permanently, but it requires a very special kind of steel to be worthy of the name of a permanent magnet under the conditions of operation to which a magneto is subjected on a motor-car.

In the ZU4 Bosch there are two horseshoe magnets side by side, their lower ends are fastened by screws to shaped cast-iron pole pieces that embrace the armature with just sufficient clearance to permit of its safe rotation. The pole pieces are only magnetized so long as they are attached to

* What follows is intended more particularly to be of assistance to anyone who has an actual magneto that can be dismantled by way of practical illustration.

the magnets; in themselves they are not permanently magnetic. They are fastened to the bronze base plate of the machine, and it is about the unit thus formed that the magneto is erected. It is noticeable in this ZU4 Bosch how much attention has been paid to many minor refinements, notably those that tend to perfect the lubrication and the protection against damp. Thus there is a felt joint between the bronze frames of the machine and the magnets, and there is also a piece of oiled paper between the two magnets. Where the armature spindle projects through the frame to receive the driving-shaft there is a felt ring carried in a groove. The object of these refinements is to make the magneto as watertight as possible. The proper state of the felt is one of oily moistness, which is maintained by a by-pass oil-way that taps the main lubricating canal to the bearings.

It is not advisable to "tinker" with magnetos, for in the first place the modern type gives little trouble if once properly set, while some of the earlier machines that were less perfect were also far less easy to reassemble once having been taken apart. Provision is made for inserting lubricant in certain properly guarded oil-holes that are readily accessible, and it is just as important not to use too much oil as it is to use sufficient. A very little lubricant goes a very long way if it is properly applied. As an instance in point, I may quote the well-known Gnome rotary engine used on aero-

planes, which will swallow over a gallon and a half of castor oil in an hour, yet I have been told of an experiment in which that engine has actually been adequately lubricated by $\frac{1}{20}$ of a drop of oil per revolution. A typical magneto such as the ZU4 Bosch has three bearings; one is situated at each end of the armature spindle, and is a ball bearing, and one is a long plain bearing for the support of the distributor wheel. The three bearings are supplied from two oil-holes on the top of the magneto frame, and the distributor bearing is fitted with a screw plug containing a felt wick that absorbs the bulk of the oil when it is first inserted and distributes it evenly during the intervening time. Occasionally, it should be removed, washed in paraffin, re-saturated with clean oil and carefully replaced. Ball bearings need very little oil for their proper lubrication. Indeed the oil in this case is not so much a lubricant as a protection for the bright surfaces which it keeps in perfect condition. A hard sphere rolling on a hard, smooth surface offers the least resistance to movement that can be devised by mechanical means, and, in principle, there is no need to lubricate the surfaces, which are in rolling and not sliding contact. It is, however, essential to take every precaution to keep them free from dust and damp.

One of the most interesting and important of the refinements in the ZU4 Bosch lubricating

system is the provision of sumps and drains for discharging surplus oil that otherwise might spread indiscriminately over vital parts not intended to be lubricated.

The armature itself and the condenser enclosed in the armature extension together form a unit that is beyond the care of the motorist. It is absolutely certain that amateur hands will do more harm than good by any attempt to set right a fault either in the armature winding or in the condenser. Their successful operation depends entirely on the perfection of their initial construction, and the nature of that work is such as to render the details quite inaccessible for general inspection.

At one end of the armature is the brass ring forming the live end of the high-tension winding. Against this ring presses a spring-loaded carbon-brush carried in an ebonite bracket. The same bracket carries another carbon-brush, making contact with a brass button on the end of the distributor spindle, which itself carries a carbon brush that revolves over the distributor contacts. All the brushes are carried in brass guides so as to make a better electrical connection, and are attached to light steel springs that are fastened to the guides above mentioned, except in the case of the distributor brush, which can be removed with the spring complete. The distributor brush is notched, and is prevented from falling out of its

socket by a spring clip. Clean contacts and free-acting brushes are the essential qualities to be maintained in this part of the high-tension circuit, and, as the magneto is entirely enclosed, there ought to be no difficulty in retaining these properties.

There is, in the high-tension circuit, a safety spark-gap formed by a brass plate projecting from the bracket that carries the high-tension collector-brush. This gap, which measures about half an inch across, is for the purpose of serving as an outlet to the high-tension electricity if for any reason it is prevented from flowing through its usual circuit. More often than not, of course, a broken plug or other fault results in a short circuit, but it may happen that a high-tension wire becomes disconnected, so that there is no circuit for the high-tension current at all. Under such circumstances the spark takes place at the safety spark-gap, and so avoids the liability of piercing the insulation at some inconvenient point that would spoil the circuit for future use.

The live end of the low-tension armature winding terminates in the long screw that holds the contact-breaker mechanism on to the armature spindle. The low-tension electricity is thus led direct to the stationary member of the contact-breaker, which is insulated from the plate supporting the mechanism. This plate, together with the rock lever carried upon it, forms part and

parcel of the armature core, so far as electrical connections are concerned; hence the low-tension winding is short-circuited so long as the contacts are closed.

Whenever the armature rotates, the contact-breakers are periodically struck apart by the action of the rock lever upon the stationary cams, and thus the circuit is suddenly broken twice every revolution. It is at the moment of break that the spark occurs, and the timing is thus obtained by rocking the member to which the cams are attached, by means of the timing-lever. In the ZU4 Bosch magneto, the cams are shaped steel shoes fastened by screws to a bronze sleeve. On the outside of the sleeve is a collar that is slightly undercut on its faces so that it may be clamped between the jaws of a lever attachment that is fastened by a screw. By this simple design the timing-lever can be set in any one of several positions to suit the arrangement of the control on any particular car. Yet another little refinement that might escape notice is the presence of a lubricating wick in one of the cams, the object of which is to retain a little oil and so keep the surfaces just sufficiently moist.

The striker lever is a steel bell crank with a platinum-tipped screw at one end for the contact, and a fibre heel at the other. This latter strikes against the cam as the armature revolves. It is designed so that it can be replaced when worn, but

the life is indefinitely long under ordinary circumstances. The contacts are held closed by a steel spring, which in appearance is like a length of clock spring. At each end, this spring is reinforced by an additional layer for a length of about half an inch. The object of this feature is to increase the strength at the weakest part, where, otherwise, it is most liable to break.

The spring is fastened by screws, and it is necessary to remove one screw if the bell-crank lever has to be taken away from the mechanism. The lever itself is held on its pivot by a spring clip, and could, otherwise, be removed without tools. The only purpose for which it might need removal is to ease the spigot bearing on which it rocks, if that happens to have become tight, as conceivably it may do if damp, for it is bushed with fibre in order that it may operate without lubricant.

The adjustment of the contact points is provided by a screw carried on the insulated contact plate ; a special spanner is supplied with the machine for the purpose of making this adjustment *in situ*. There is apt to be some confusion of thought as to the significance of the virtue of some precise amount of " break," that is to say, in the exact distance apart to which the platinum tips move when the heel of the bell-crank lever strikes the cam. In the first place, the mechanism of the magneto is such that the adjustment of the contact

screw determines the moment at which the points separate, and so the extent of the gap does to a slight extent affect the timing. This is due to the fact that the edges of the two cam plates are bevelled, and thus afford a range of positions where the heel of the contact lever first strikes against them. If the adjustment screw is drawn back, the heel of the contact lever moves outwards and so strikes against the bevelled edge of the cam plate sooner than would otherwise be the case. As the contacts then first separate when the heel is still low down on the bevelled edge of the cam, the gap between the platinum tips increases as the heel rides up on to the parallel part of the cam. Conversely, if the adjustment screw is moved inwards, so is the heel of the contact lever drawn inwards too, and if the adjustment is carried to excess the heel might miss the cam altogether. Between these extremes there is naturally an adjustment that affords the most suitable mean position, and so contributes most to the proper harmonious working of the magneto as a whole.

There is, however, a more important consideration than the above, and it relates to the slope of the cam face at any point. The slope determines the *rate* at which the contacts separate, and a quick break is everything. So long as the slope is constant, the break will be equally quick, independently of the allowable distance to which the points separate. Just where the wedge part

of the cam runs into the parallel part, the surface is rounded over and the slope changes. If the adjustment is set for a *very* fine break, therefore, the heel may strike this less steep part of the cam and so make a slower break. A slower break is conducive to sparking at the contacts, and as, in addition, the points do not separate very far, the spark, if it occurs, has an excellent opportunity to persist, and " pit " the platinum surfaces.

It is, therefore, worth while taking trouble to make the adjustment properly. The usual dimension of the gap is about half a millimetre.

It should be needless to remark that the platinum-tipped contacts must be kept clean and flat, so that when they come together they may serve instantly to close the circuit. The circuit is closed by the fact that the bell-crank lever is in natural electrical connection with the plate carrying the contact mechanism, which in turn is carried by a portion of the armature frame to which one end of the primary winding is " earthed." The condenser is permanently connected between the live end of the primary winding and the armature frame, and so remains across the gap of the contact-breaker when the points are separated.

There is, on the Bosch magneto, a carbon brush projecting from the back of the contact-breaker plate so as to make electrical connection between that member and the frame of the magneto. The object of this brush is to ensure a proper circuit

for the switch, the live side of which is coupled up to a terminal on the cover plate over the contact-breaker. This terminal is connected by a spring contact with the live end of the primary winding. When switching off a magneto the object is to render the contact-breaker ineffective while operating, by permanently short-circuiting the gap. It is thus necessary to arrange the switch so that the "off" position from the point of view of switching off the magneto corresponds to what the electrician would ordinarily describe as the "on" position from the point of view of the switch. That is to say, when the magneto is "off," the switch circuit itself is closed, and when the magneto is "on," the switch circuit is open. In the absence of the earthing brush on the back of the contact-breaker plate, the switch circuit could only be completed via the ball bearings on which the armature spindle is supported.

Two other earthing brushes are also provided in the sides of the magneto frame, and they press directly upon the condenser-casing. Thus, between them these earthing brushes secure a thoroughly efficient electrical connection between the revolving members and the stationary members of the magneto, and so avoid any possible faultiness in the earth return circuit whether from the plugs or from the switch. It is extremely important to recognize the requirements of the current of the electricity that flows back to the magneto from the

ignition-plugs. Electricity does not flow at all except in a closed circuit, and the mere use of an "earth return" does not avoid any of the liabilities that would properly accompany the fitting up of a return wire. The earth return is a convenience, but its essential qualities must not be neglected on that account. The electricity is led to the ignition-plugs by properly arranged cables connected to the plug terminals and to the distributor, and it is equally important to ensure that the return circuit from the body of the plug via the cylinder casting to the magneto frame and so to the armature core is rendered equally perfect.

So far as the connection between the body of the plug and the cylinder casting is concerned, the screw thread with which the plug is fixed ensures that there shall be no fault. The cylinders themselves make a metal-to-metal joint with the base chamber, and on a bracket projecting from this the magneto is ordinarily carried. There remains only the connection between the magneto frame and the armature core, which is nominally established through the ball bearings, but is made more perfect by the carbon brushes just described. Where a magneto happens to be carried on a bracket that is insulated from the engine, it is important to complete the earth return by a wire from the magneto frame to the cylinder casting. Similarly, in the case of the switch, the lever pivot of which must be permanently connected by a

wire to some part of the magneto frame or to a member that is permanently connected to the frame.

The term "earth" in connection with the return path of the circuit is derived from the use of the earth itself in some forms of outdoor electrical operations. Although earth itself, as such, and in small quantities, is not a good conductor of electricity, the earth as a whole will serve this purpose. It is, however, not always suitable in electrical undertakings to use the earth, but the term "earth return" has been applied to cover the use of other available objects not primarily designed as electrical conductors. Thus, the earth return of an electric tramway system consists of the rails, which are bonded together with copper tabs. Similarly, the metal of the engine of a motor-car serves as the earth return for the magneto circuit.

When speaking of the high-tension circuit of a Bosch magneto, mention was made of a special point about the armature winding. The peculiarity consists in earthing the high-tension coil through the low-tension coil instead of separately to the armature core. In consequence, the low-tension coil forms part of the high-tension circuit while the spark takes place, and the manufacturers claim to have found from experiment very material benefit from this combination. Accepting the statement as fact, I must, however, confess to

being unacquainted with a full explanation of the theoretical advantages. It would seem that there is more than one point of view from which to consider the question, but so far as a diagram of connections is concerned the only essential difference in the system is that the secondary circuit forms a parallel circuit across the condenser terminals, whereas ordinarily the high-tension system has no direct electrical connection with the condenser.

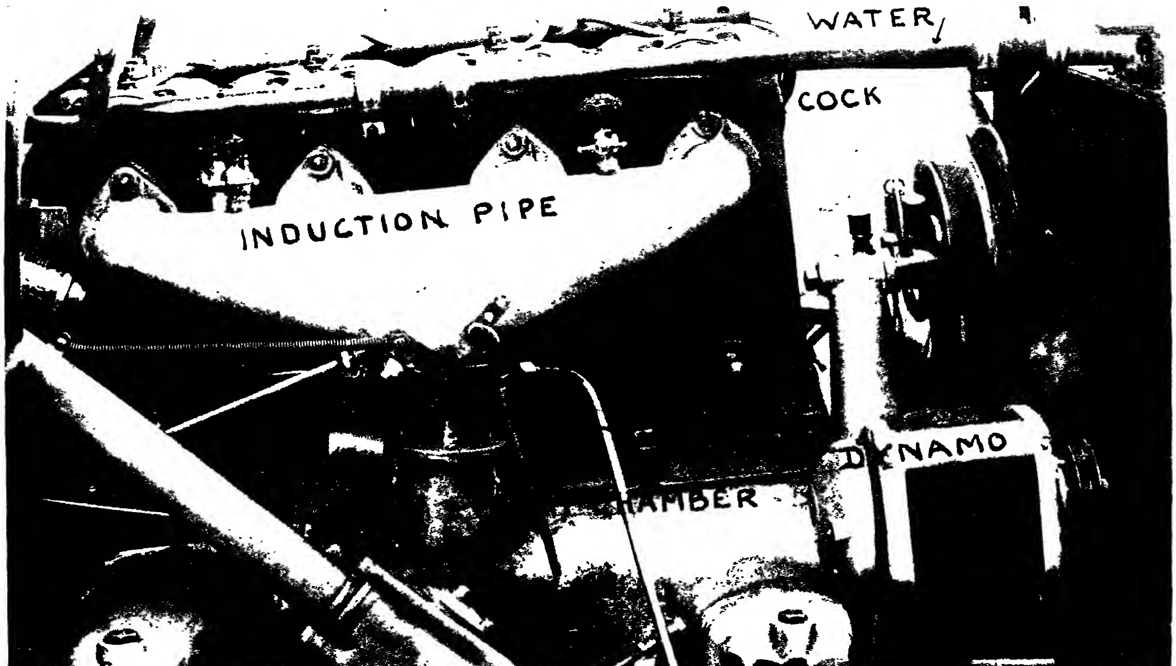
Of the magneto as a complete unit, I have now said as much as properly comes within the scope of this chapter. There remains, of course, the question of driving the armature, and also the question of timing the magneto whilst it is in use. Of these matters the former relates to the detail of chassis construction, while the latter lies within the art of driving the car, and on both something has already been said elsewhere.

CHAPTER XI

THE DYNAMO

BY the time that electric light has become a standard fitting on cars, very few people will stop to remember that there has been any difficulty associated with its introduction. I do not here refer so much to the natural tug-of-war existing between a novelty and an old-established system, such as acetylene, but I am thinking more particularly of the electrical and mechanical problems associated with the design and construction of a successful electric light equipment for motor-cars.

To appreciate the situation fully it is necessary to understand a little about the fundamental action of a dynamo; but that which it is necessary to know for this purpose lends itself to a fairly simple explanation, more particularly as the dynamo is essentially the same kind of machine as the magneto, which has already been described in full. The magneto is arranged to deliver impulses of electricity that synchronize with moments at which sparks are required at the ignition-plug. These impulses alternately force the flow of electricity in opposite directions. The dynamo,



THE DAIMLER ENGINE WITH A DYNAMO FOR ELECTRIC LIGHT AND AUTOMATIC STARTING

The C.A.V. dynamo is driven by a link belt from a pulley on an extension of the crank-shaft

on the other hand, is designed to deliver a steady electric pressure so as to cause a current to flow constantly in the same direction.

In both cases, the electricity is generated in a coil of wire that is wound on an iron core in such a fashion that the finished object forms a cylindrical or drum-shaped member known as an armature. This armature is situated between the poles of the magnets, and is there rotated in the presence of the invisible, but nevertheless existent, magnetic field. The presence of the magnetism, although invisible, makes it a very much harder business to rotate the armature than would be the case were the magnets removed, yet there is no physical contact whatever between the armature and the magnets.

The energy put into this rotation, when the armature is driven by the engine, reappears as electricity in the armature coil, and is, subsequently, converted into light by the incandescence of the filament in the bulb. The mere rotation of the armature between the pole pieces of the magnet suffices to generate the electricity, but it depends on how the wire on the armature is wound as to the nature of the electric force that is produced. The simplest possible form of winding is that employed on a magneto, but its utility is limited to the production of two impulses of electricity during each revolution. For the purposes of ignition this serves very well, because it

is possible by means of gearing to arrange that these impulses shall synchronize with the requirements of the engine.

It would also be possible to light an electric lamp by the aid of electricity of this kind, and, indeed, most of the commercial electric light in houses and elsewhere does, in fact, consist of impulses that alternate in their direction of flow. When the alternations are rapid, the filament of the lamp has no time in which to cool down, and the retina of the eye is insufficiently sensitive to appreciate any variation in the brilliancy of its light.

Were it possible satisfactorily to operate electric light on motor-cars directly from the generator itself, there would be no reason why the magneto type of machine should not be employed for the purpose. There is, however, the fundamental consideration that the electric light is often needed when the car is stationary, and it would be altogether out of keeping with the convenience of electric light itself if the engine had to be kept running merely for the sake of the side and tail lamps being lit in accordance with the law.

For this reason alone, it is essential that any electric light equipment on a motor-car should include the use of a battery of accumulators for the purpose of acting as a storage place from which electricity can be obtained when the dynamo is not in action. The accumulator is a contrivance whereby chemical reactions are set up through the

agency of electricity, and these, in turn, give rise to electrical action. Accumulators are thus available, so long as they contain any of the initial charge of electricity, for the purpose of lighting the lamps at any time, whether the car is at rest or in motion

Also, the electric accumulator has the advantage of delivering its current at a uniform pressure throughout the greater part of its discharge, and, in consequence, it is able to maintain a steady light under conditions that are easy upon the filament of the lamp. On the other hand, the accumulator ought to be charged under equally steady conditions if it is to be maintained for a long period economically in active service. Herein lies, therefore, the fundamental problem to be overcome in designing a satisfactory dynamo for use on motor-cars.

In order to charge accumulators, current from the generator must flow always in one direction, consequently the alternate impulses, as derived from the ordinary magneto, are unsuitable for the purpose, although there is, as a matter of fact, a magneto type of generator that has been adapted to suit electric lighting requirements. Moreover, apart from this fundamental aspect of the problem there is also the consideration that the electric pressure generated by a dynamo varies with the speed of its rotation, which is directly proportional to the speed of the engine ; consequently,

unless the ordinary dynamo is suitably modified in respect to its internal construction, or has some special form of driving mechanism, it is fundamentally unsuited to the requirements of car lighting.

It will be seen from what has just been said, that there are two methods of tackling the problem. One system is so to wind the armature and to arrange the internal economy of the dynamo generally that it will never give a higher voltage than a certain predetermined maximum, the other system is to arrange the coupling between the dynamo and the engine so as to prevent the dynamo being driven at a higher speed than a certain predetermined maximum.

Both methods are in vogue, and at present appear to be giving equal satisfaction. I do not propose entering into a technical discussion of the ways and means of electrically regulating the output of the dynamo from within. Suffice it to say that the flow of electric current in the armature itself creates a magnetic field that can be used partially to neutralize the magnetism of the main magnets. As it is upon the strength of the magnetism in which the armature revolves that the voltage depends, it is apparent that the regulation of the magnetic field affords a direct means of limiting the output.

The mechanical method of regulating the speed of the dynamo consists of some form of slipping

clutch, which automatically releases the connection between the engine and the dynamo when the engine runs faster than the predetermined speed. The success of this system depends on the nicety with which the controlling apparatus is made to maintain uniform rotation without "hunting," that is to say, without any tendency for the armature speed to fluctuate considerably above and below its mean value.

No matter what form of regulation may be employed for the purpose of limiting the output of a dynamo, it is apparent that it cannot maintain a voltage below a certain engine speed. When the dynamo is driven so slowly that it fails to generate a voltage equal to that of the accumulators, the accumulators will discharge electricity through the dynamo, and a certain amount of the current will thus be wasted.

In order to avoid this waste, it is common practice to fit what is known as a "cut-out," which is a simple electro-magnetic switch that operates on exactly the same principle as the hammer of an electric bell. When the voltage of the dynamo exceeds a certain minimum, the electro-magnet closes the circuit to the accumulators, and charging commences. When the voltage drops below this minimum, the current from the accumulators demagnetizes the electro-magnet, and the switch opens the circuit automatically.

Sometimes the cut-out is not fitted, on the

grounds that it is an added complication. In this case, the motorist has to be sure to switch off his charging switch every time he stops his car, and also whenever he is running unusually slowly. When current from the accumulators passes through the dynamo, the dynamo rotates of its own accord as an electric motor, and if the car is at rest it is generally possible to hear its action owing to the click of the free-wheel through which the armature spindle is, in such systems, driven by the engine.

The pros and cons of electric light on cars have often been discussed in the Press. Electric light starts out with the advantages of convenience and cleanliness. As a system, it requires intelligent care, and, in the first instance, it may seem rather more complicated than an acetylene plant, particularly when the acetylene generator is of the simplest kind, or the dissolved acetylene cylinder is used in its place.

The electric equipment has the disadvantage of greater weight and greater cost, particularly when the capacity of dynamo is very high. As at present used the electric bulbs in head-lights are seldom as powerful in nominal candle-power as a really good acetylene flame, but they are more certain of maintaining a steady light and they can be focussed with great facility, which is an important point in securing the proper illumination of the road.

Its convenience alone, however, is sufficient to ensure its use by many motorists now that thoroughly reliable systems are readily available, for there can be no question that the ability to switch on at any time without leaving the driver's seat is a very good advantage that is greatly appreciated. It may not be difficult to light up with a match, but the real point is that it is so often a nuisance to have to do so, particularly to the man who drives his own car and who likes to be able to use it at a moment's notice.

CHAPTER XII

PETROL AND ITS SUBSTITUTES.

HYDROCARBONS OF INTEREST TO THE MOTORIST

1. The Paraffin series C_nH_{2n+2}

Methane	CH_4		Gas.
Ethane	C_2H_6		
Propane	C_3H_8		
Butane	C_4H_{10}		
Pentane	C_5H_{12}	boils at 37° C.	
Hexane	C_6H_{14}	,, 69	" Petrol."
Heptane	C_7H_{16}	,, 98	
Octane	C_8H_{18}	,, 120	
Nonane	C_9H_{20}	,, 130	
Decane	$C_{10}H_{22}$	,, 158	Kerosene lamp oil.
Undecane	$C_{11}H_{24}$		Solar and Fuel oil.
Duodecane	$C_{12}H_{26}$		Lubricating oil.
Tredecane	$C_{13}H_{28}$		Vaseline.
etc. etc.	$C_{27}H_{56}$		Paraffin wax.

2. The Olefine series C_nH_{2n}.
   Ethylene C_2H_4, etc.

3. The Acetylene series C_nH_{2n-2}.
   Acetylene C_2H_2, etc.

4. The Benzene series C_nH_{2n-6}.

Benzene C_6H_6	boils at 81° C.	Benzol.
Toluene C_7H_8	,, 111° C.	
Xylene C_8H_{10}		
etc.		

5. The Naphthalenes C_nH_{2n-12}.
   Naphthalene $C_{10}H_8$ boils at 218 C.

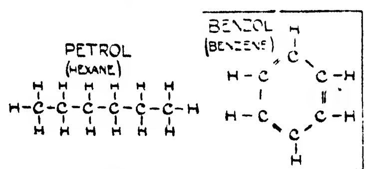
6. Alcohol C_2H_5OH.
   Methylic Alcohol CH_4O boils at 63° C.
   Ethylic ,, C_2H_6O ,, 78° C.

"PETROL" is a trade name that was originally invented by Messrs. Carless, Capel and Leonard for the petroleum motor spirit supplied by them in the early days of automobilism, but so appropriate was the choice of the word that it became a generic in motoring terminology and so ceased to be an exclusive title for a particular brand. It was an admirable term to choose, because its final syllable "ol" was already in use as a distinguishing mark implying the commercial article. "Benzol," for example, is the commercial spirit of the benzene series; nothing, therefore, could have been more fitting than to call the corresponding commercial product of petroleum by the simple word "petrol."

Petroleum as it comes from most wells has for its principal constituent the paraffin series of hydrocarbons, which range from gases to solids. A table showing some of the members of the series is given on the preceding page, and the place occupied by "petrol" is indicated. The gaseous members serve to force the natural oil to the surface of the earth, and the various commercial groups are obtained from the crude mixture by distillation.

The increase in the demand for "petrol" has been so much more rapid than the rate at which the commercial demand for other petroleum products has increased, that a virtual famine has occurred in the very light spirit.

Obviously, it does not pay to mine petroleum for the sake of "petrol" alone; indeed it is quite essential that all the other "fractions" should find a commercial outlet if "petrol" is to be sold at a reasonable price. In order to adjust the supply to meet the demand, oil producers now distil fractions of heavier densities and higher boiling points into the "petrol," which formerly were excluded. The specific gravity of commercial "petrol" has thus steadily increased of late years.



Stereo formulæ for hexane, C_6H_{14}, one of the principal constituents of "petrol," and benzene, C_6H_6, one of the principal constituents of "benzol." Petrol and benzol are entirely different substances, as different as the mere appearance of these formulæ, which graphically represent the carbon and hydrogen atoms in their molecules. It is, therefore, important not to confuse them Benzol is a by-product that can be recovered when coal is distilled at high temperatures (1200° C.) for the manufacture of illuminating gas or the special coke that is used for metal melting. When coal is distilled at low temperatures (450° C.), the tar contains hydrocarbons of the paraffin series, which, therefore, yield petrol.

It is interesting to remark, however, that Messrs. Carless, Capel and Leonard still supply a doubly distilled spirit of standard sp. gr. = 0·700 for those who require, for testing purposes or otherwise, a petrol of guaranteed value.

In the ordinary course of events, the petrol of commerce that is supplied from the oil wells must continue to get heavier as time goes on, for the output of any specific grade of spirit that is recoverable by any simple process of distillation

is strictly limited to the natural contents of the crude material.

It has been explained that the crude oil as it comes from the earth contains a range of light hydrocarbons that collectively are called "petrol" on the English market. They are separated from the crude petroleum by distillation—that is to say, they are evaporated and recondensed. By any straightforward process of distillation it is impossible to increase the amount of petrol beyond the quantity originally contained in the crude oil. This quantity varies widely in different localities, being in the order of 10 per cent for the oilfields that produce the Shell spirit as it has hitherto been supplied.

An experiment of great interest and importance, made in 1871 by Thorpe and Young, resulted in the discovery that the repeated redistillation of a heavy hydrocarbon under a temperature in excess of its boiling point, and under a pressure greater than atmospheric, resulted in its conversion into lighter fractions. Paraffin wax was, in fact, by this means converted into spirit. In the experiment, it was distilled and redistilled from one end to the other of a bent, sealed tube, which afforded a simple means of obtaining the requisite temperature and pressure. The term "cracking" is applied to this operation in order to distinguish it from ordinary distillation.

The story is also told of the independent dis-

covery in America of the same effect, which was noticed as occurring on an occasion when the process of distillation was proceeding so *slowly* that the lighter fractions were allowed to condense on the roof of the still and to fall back into the hot oil, which had a temperature in excess of the boiling point of these lighter fractions themselves. It was found that the quantity of spirit so produced from a given quantity of crude oil was somewhat increased by allowing this cracking action to take place.

More recent developments, which are still in an experimental stage, have drawn attention to possible advantages from a process that cannot adequately be described as ordinary "cracking."

This process, briefly, consists in feeding oil and water simultaneously into a heated retort that contains a suitable catalyst such as nickel or iron. The retort is maintained at a temperature in the order of 600° C., and in some processes is also under high pressure, but the high pressure is clearly a disadvantage in any apparatus that is simultaneously subjected to great heat.

The catalyst, which, in one process with which I am acquainted, consists of iron turnings, while another apparatus uses nickel rods, has the effect of *accelerating* the conversion of the heavy oil into lighter fractions, but is, in itself, unaffected by the change. Precisely what happens inside the retort is not clearly known, although theories on

the subject are not lacking. The nature of the process suggests a synthetic action, and for this reason I have generally called motor spirit thus produced "synthetic petrol." For the moment, however, it is more important to know whether such a process is or is not of such a character as may be commercially useful.

That it is of great interest is apparent on the face of it, and that it is of potential importance is equally self-evident, but it has not yet been developed to a point at which it is possible to say more than that the broad principle is one of promise. By this I do not mean to say that any such process is capable of effecting an immediate reduction in the price of petrol. It would, however, be of the utmost utility to have satisfactory means of increasing the proportion of petrol available from crude petroleum, because the demand for the lighter hydrocarbons would probably make it worth while to work such a process, provided it could be operated at a reasonable figure.

The estimated cost of producing "petrol" from fuel oil, for example, is, I understand, in the order of 1½d. to 2d. a gallon, but everything naturally depends on the market value of the residue.

The consumption of petrol in England during the past eight years has more than quadrupled. In 1905 the consumption was 18 million gallons, last year it was 80 millions. The intervening annual amounts were as follows: 25, 34, 40,

53, 55, and 70 millions. From 1911 to 1912 the increase was 10 million gallons. If the increase continues at this rate it is self-evident that the competition for supplies must inevitably become so acute as to make the price prohibitive unless new sources of petrol are developed with corresponding rapidity.

Professor Vivian Lewes, who has for several years voiced a warning of the danger of a shortage in the liquid fuel supply, said in his Cantor Lectures of 1913: "I doubt personally if in fifty years' time it [oil] will be obtainable at a price that will enable us to use it commercially."

According to the same authority, the world's output of petroleum is now nearing 50 million tons per annum, which is made up as follows:—

United States ..	63·99 per cent	Mexico	1·02 per cent
Russia ..	21·48 ,,	Japan	·59 ,,
Galicia.. ..	3·87 ,,	Peru	·40 ,,
Dutch E. Indies	3·37 ,,	Germany ..	·32 ,,
Roumania ..	2·97 ,,	Canada ..	·10 ,,
India	1·87 ,,	Other sources ..	·02 ,,

Corresponding figures given in the *Petroleum Review* for 25 January, 1913, are as follows:—

	1912.	1911.
United States.. ..	220,000,000 barrels	220,400,000 barrels
Russia	63,000,000 ,,	62,000,000 ,,
Roumania	12,500,000 ,,	10,800,000 ,,
Galicia..	8,000,000 ,,	9,000,000 ,,
Netherlands India ..	13,000,000 ,,	11,600,000 ,,
British India	7,500,000 ,,	7,200,000 ,,
Mexico	16,000,000 ,,	9,500,000 ,,
Other countries ..	10,000,000 ,,	7,000,000 ,,
Totals	350,000,000 ,,	337,500,000

(N.B.—7 barrels = 1 ton approx.)

A study of such a table conveys little or nothing to the English motorist, however, for it in no sense indicates the relative importance of these different sources so far as his supply of petrol is concerned. Thus, of the above total, about 1½ million tons of petroleum products of all sorts reached the United Kingdom from the following sources :—

United States	980,000 tons	Russia	120,000 tons
Dutch E. Indies	160,000 ,,	Other countries	96,000 ,,
Roumania ..	144,000 ,,		

Now compare this table with the following particulars of the sources of England's supply of *petrol*, which I also quote from Professor Lewes's Cantor Lecture :—

Dutch E. Indies	40 million gals.	Russia ..	5 million gals.
America ..	16 ,,	Roumania ..	4 ,,
Holland ..	6 ,,	Other countries	9 ,,

Holland, Russia, and Roumania, it will be observed, lie on the Eastern route, and most of the spirit that they contribute may for present purposes be regarded as "Shell," for the transport is mainly in the hands of this company. Carburine and Movril, for example, come from the East; Mex, however, is a product of Mexico, but the transport facilities from that country are as yet comparatively undeveloped.

In the future, it is certain that the products of the Mexican fields will greatly influence the world's markets; so likewise may those of Trinidad. When the Panama Canal is opened the

Californian fields will presumably find an outlet by water that should materially affect their contribution to the European supplies. The relative importance of these fields lies, of course, primarily in the fact that they are already known and have already interested the capitalist; but their basic significance as new sources of liquid fuel rests, it is evident from what has already been said, on the rate at which the demand for petrol is outstepping the supply.

Owing to expanding internal consumption, America's export trade in mineral oil decreased in 1912 by about 21 million gallons, but the value of this business nevertheless showed an increase of £3,000,000. In the first eleven months of 1912, America *imported* 251,706,824 gallons of crude oil as compared with about 48¼ million gallons in the corresponding period of 1911.

England is not the only country that needs liquid fuel, and even were it produced inside the kingdom, British gold would still be the only magnet of any consequence that would attract the petrol fractions into the British motorist's tank, for a profit is about the only consideration for which commerce shows any marked preference.

In the foregoing summary of the position it is apparent that it is very necessary to keep the mind clear as to the supply and demand for crude oil and for petrol. The world's supply of crude oil, as such, is unquestionably capable of expan-

sion beyond present needs, but it does not necessarily follow that the *natural* petroleum products will afford the increase in the supply of petrol that is quite clearly needed to meet the present growth in the demand. For this reason, any commercially satisfactory process for the synthesis of spirit from oil that ordinarily provides a poor yield ought to have a field of great utility.

Those interested in studying in greater detail the chemistry of synthetic petrol, may with advantage refer back to the experiments of P. Sabatier and J. B. Senderens conducted some ten years ago. Convenient abstracts of their work may be found in the journals of either the Chemical Society or the Society of Chemical Industry, which between them cover the greater part of the field of chemical research. One such that it may be of interest to quote in full appears in volume xxi. p. 853, of the *Journal of the Society of Chemical Industry* for 1902. It is a contribution by the above-mentioned authors to the theory of the formation of natural petroleum, and relates, as will be seen, to the synthesis of varieties of hydrocarbons.

"The liquid obtained along with ethane, when hydrogen and acetylene are passed over reduced nickel below 180° C., consists almost entirely of paraffin hydrocarbons; and in density, boiling points, and other physical characters, it resembles very closely American petroleum. Pure acetylene,

passed over reduced nickel, has been shown by Moissan and Moureu to become incandescent, and to yield carbon, hydrogen, and benzene hydrocarbons. If a long column of nickel be used, the farther portions cause the reaction of the hydrogen on the benzene hydrocarbons; and if the liquid products of this reaction be vaporized, and passed together with hydrogen over reduced nickel at 180° C., a mixture of paraffin and derivatives of cyclohexane constitutes the liquid portion of the product, similar to Caucasian petroleum. If the second passage over nickel be carried out with the metal above 300° C., the cyclohexane derivatives are in part decomposed, and the liquid product resembles Galician petroleum.

"The author considers that natural petroleum may have been formed from hydrogen and acetylene, produced by the reaction of alkali or alkali-earth metals and carbides on water, meeting with metallic nickel, cobalt, or iron, and producing, according to their proportions, and to the temperature of the reaction, paraffins alone, or mixtures of paraffins and cyclic hydrocarbons, as in the above experiments."

Acetylene being itself a hydrocarbon of the form C_2H_2, while the paraffins as a series correspond to the ratio C_nH_{2n+2}, the synthesis of the latter from the former by the use of hydrogen in the presence of a metallic catalyst is apparently of the same general character as the synthesis of petrol.

In any case, it is evident that Sabatier was led

in due course to investigate this aspect of the problem, for we find him taking out a French patent, No. 400,141, on 21 May, 1908, relating to a process for transforming crude petroleum into spirit. It is thus described in the *Journal of the Society of Chemical Industry*, p. 974, vol. xxviii., 1909 :—

"The oil is vaporized and passed over finely divided metals heated to between 400° C. and a dull red heat. It is converted partly into gas and partly into low boiling, unsaturated, oxidizable bodies of unpleasant odour. The latter are passed along with hydrogen or gases rich in hydrogen over finely divided metal, preferably nickel, heated to between 150° C. and 300° C., in order to obtain products not having an unpleasant odour. The two stages may be combined so as to form a continuous process."

In his Cantor Lectures of 1886, Sir Boverton Redwood made the following remarks on the subject of cracking :—

"The yield of burning oil from a crude petroleum of given quality has been largely increased during recent years. This has been accomplished by the adoption of the process known as 'cracking.' We have seen that the crude petroleum produced in the States of Pennsylvania and New York consists principally of the hydrocarbons known to chemists as paraffins. The researches of Thorpe and Young have demonstrated that paraffins (C_nH_{2n+2}), when heated to temperatures

above their boiling points, are converted into olefines (C_nH_{2n}), carbon being deposited, and gaseous products evolved. It is this operation of dissociation which is called 'cracking,' and its employment enables the refiner to break up the hydrocarbons which are too heavy to be burned in ordinary lamps, and too fluid for use as lubricants, and convert them into hydrocarbons which may be allowed to pass into the burning oil distillate without unduly increasing its density. The process of cracking is carried out by conducting the operation of distilling the burning oil so slowly that the less volatile hydrocarbons become condensed on the upper part of the still, and fall back into the heated oil, where they are heated to temperatures above their boiling points, and become 'cracked.' A far larger yield of burning oil is thus obtained. The gaseous products are conducted into the still furnace, and serve as fuel. . . . I have pointed out that when paraffins are heated to temperatures above their boiling points, dissociation occurs and olefines are produced,

$$C_{20}H_{42} = C_5H_{12} + C_{15}H_{30} = C_7H_{16} + C_{13}H_{26}, \quad \text{etc.}$$

At a very high temperature, hydrocarbons containing still less hydrogen are produced. This well-known fact has been taken advantage of by Mr. Nobel to manufacture from Russian petroleum residue, or astatki, benzene, naphthalene, and anthracine. The process employed consists in breaking up the astatki on the highly heated floor of a cupola regenerating furnace. The first distillation thus effected is stated to yield from 30 to

40 per cent of tar, containing from 1·75 to 17 per cent of 50 per cent benzol. . . ."

In the history of petroleum refining, and particularly in connection with the early days of the Scotch shale oil industry, which preceded the development of the American fields, various patents were taken out for the admission of water or steam with the oil, and the use of scrap iron or the like in the retorts. The afore-mentioned references and brief notes should form some guide to those who may at this point be desirous of "looking up" a subject somewhat outside the ordinary scope of their motoring interest.

There are two distinct schools of thought concerning the causes that have produced the great subterranean petroleum reserves, one believing them to have been generated by chemical reactions, while the other considers that they have been formed, after the manner of coal beds, by the slow decomposition of vegetable matter.

Although there is no proof one way or the other, the question is one of wide, general interest, and appeals with some directness to motorists. There is, however, not even this excuse needed for the publication of so fascinating an account of the pros and cons of the situation as was given by Professor Vivian Lewes in his 1913 Cantor Lectures at the Royal Society of Arts :—

"The origin of petroleum is purely a matter of

surmise, and many theories have been adduced from time to time to account for its formation. There is no doubt, as I pointed out long ago, that the primary rocks which form the basis of the world contain practically little or no carbon, and consist of fused and crystalline masses of silicates and other compounds produced at very high temperatures, and that where bitumen and hydrocarbons are found in lava and contained in pockets in out-crops of igneous rocks, it has got there by the disturbance of carboniferous strata by the molten rock. It is a fair inference that the carbon which we now find present in the large class of sedimentary carbonates in the earth, and the carbon in coal, oil, and other carbonaceous material, have been derived from the carbon dioxide originally present in the prehistoric atmosphere. Everything, therefore, points to the early atmosphere of the world consisting of a mixture of nitrogen, carbon dioxide, and some oxygen, but it is clear that, even supposing that the ratio of nitrogen to oxygen was not greatly different to that existing in the atmosphere of the present day, it must have been so diluted with the excess of carbon dioxide that, instead of there being 2.09 per cent by volume of oxygen, there was probably only a fraction of this quantity, and under these conditions decay, as we now understand the term, would have been almost unknown, and would have been much more akin to fermentation.

"In a previous course of Cantor Lectures on the 'Carbonization of Coal,' I pointed out that this

was the only really satisfactory explanation of the vast accumulations of vegetable matter needed to give the thicker seams of the coal formation, and that these actions, taking place during the carboniferous and tertiary periods, gradually absorbed the excess of carbon dioxide from the air and replaced it with oxygen, the factor of change being the growth of vegetation under the influence of the sun's rays. There is not the least doubt but that it was during this same period of geological time, commencing perhaps even slightly earlier, and reaching its zenith in the tertiary age, that the formation of oil took place, or, at any rate, that the deposits of material accumulated which afterwards, under conditions of pressure and terrestrial heat, gave oil as one of the products of their decomposition.

"The theory of the formation of oil which has been the one most favoured by the theoretical chemist has been that the oil is the product of the action of steam at high temperatures on metallic carbides, taking place probably at great depths, and that the hydrocarbon gases and oil have then found their way into and collected in the strata in which the oil is now found. Such brilliant chemists as Bethelot, Mendeleeff, and Moissan have all given their allegiance to this theory, the latter chemist showing that the carbides of some of the rarer metals, when acted upon by water, yield hydrocarbons of much the same character as those found in the crude oil.

"The first factor, however, which seems to cast doubt upon any such theory is that there are no

signs of these vast deposits of carbides existing or ever having existed, whilst to the practical man who has any knowledge of the oilfields, the evidence that at once disposes of this theory is that one may find a porous stratum of limestone or sandstone which is oil bearing, whilst strata of identical character below it at a greater depth, and also above it, contain no trace of oil, so that it is evident that the oil has been formed in the strata in which it is found, and no theory which necessitates its formation elsewhere and gradual infiltration into the strata is admissible.

"In the same way it has been suggested that petroleum has been produced by the heating of already formed deposits of shale, lignite or coal by the intrusion of igneous rocks, but in the oil-bearing measures themselves signs of such volcanic action are rarely to be found, and although one knows that such actions have given small quantities of oil in the coal seams, lignite, shale or even peat deposits, it would be absurd to attempt to explain the vast volumes of oil formed in the large oilfields without being able at any rate to adduce proof of what has become of the residual carbon from the action, as although lignite and even bituminous coal are found in many fields, they have evidently not undergone any such process of distillation. It may be taken as practically impossible that either of these theories can account for the production of the oil deposits.

"All the evidence that can be collected goes to prove that the oil is of organic origin, and many

observers have ascribed it to the checked decomposition over long periods of animal remains from the low forms of fish life. There are several points in favour of this, as undoubtedly brine and salt deposits are nearly always found in the oil-fields, and in most cases with the oil itself, whilst fossilized deposits all point to a marine origin, and the work of Engler and Hofer shows that oil can be produced from such forms of animal matter.

"Practical considerations, however, make it perfectly clear that, even taking into account the differences between the atmospheric conditions then and now, which would affect not only terrestrial but marine growth, it is impossible to ascribe the origin of the vast quantities of petroleum occurring in nature to any such source, although it is not only possible but extremely probable that some portions of certain oil supplies have been formed in this way.

"The strata which constitute the storage for the oil are of a sedimentary character, consisting as they do of porous sandstone and limestone, both of them substances which might well have been formed from marine drift and deposits, whilst the limestone is known to consist largely of deposits either of substances like coral or the shells of myriads of minute forms of marine organisms, and I have always held the view that the real source from which the main bulk of oil has been derived was marine vegetation, which, under the conditions existing in those early days, probably grew in shallow seas in far greater quantities than are found at the present day. I am perfectly

well aware that some authorities of wide experience are opposed to this view and hold it up to scorn, but all I have seen points to this being the real source to which we must look as the original matter from which the chief bulk of oil was formed.

"The utilization of seaweed for the production of various commercial commodities, as has been pointed out, led to a good deal of work being done upon it during the last century, and researches made by Mr. E. C. Stanford showed that when any kind of seaweed was submitted to destructive distillation at a low red heat, large volumes of gas were evolved and an oily tar was produced, which on redistillation yielded paraffin oil (as he termed it) in considerable quantities; from a ton of weed of the genus *fucus*, which is the most common marine growth, it is possible to obtain 6·7 gallons of oil, and this particular kind of weed contains the least iodine and the largest proportion of sulphates in its ash. The following table gives the figures for this weed:—

Fucus vesiculosus (Bladder-wrack).

Water	71·00	Composition of soluble ash—	
Organic matter	23·28	Sulphuric acid	4·165
Ash, soluble	4·10	Alkalies as chlorides	11·400
Ash, insoluble	1·62	Iodine	·00985
	100·00		
On dry weed—		Per ton of dry weed—	
Organic matter	80·358	Volatile oil	354·5 ozs
Ash, soluble	14·079	Naphtha	220·8 ,,
Ash, insoluble	5·563	Paraffin oil	515·4 ,,
	100·000		

"In distilling the weed a dull red heat was

employed, and in consequence some compounds were formed having the same characteristics as those evolved from coal; but when distilling coal, the lower the temperature the more paraffinoid becomes the nature of the tar, and when the lowest possible temperature is used paraffins and naphthenes of the kind found in crude petroleum are always present in considerable quantity, so that with a distillation such as has taken place in nature, in which the material has been subjected to a comparatively low temperature for an enormous period of time, one would expect that the character of the distillate would resemble very much that of crude oil.

"It is interesting to note also that peat, when subjected to destructive distillation under the same conditions of temperature as the marine weed, yields an oily tar, from which by redistillation and purification oil of the same character can be obtained, and also solid paraffin, but the quantity of the oil is rarely one-half that obtained from the weed.

"It cannot be insisted upon too strongly that in the great natural processes of carbonization which have converted vegetable growths into coal and oil respectively, there have been countless ages of time and moderate temperatures taking the place of short periods of high temperature, and from everything we know of the nature of the changes induced in carbohydrates and hydrocarbons by heat, we should have expected the results that are found.

"The broad question that remains is, Why in

the one case should bodies of much the same character be converted into the solid conglomerate which we call coal, and under other conditions differing but little, be converted into the mixture of liquids which we know as oil?

"As before pointed out, structure has probably a great deal to do with this, but it must also be remembered that in marine silt the weed will be intermixed with sand or shell, and the mass action of a huge and uniform bulk of fermenting matter will be checked by subdivision, and the actions rendered slower than with terrestrial vegetation; whilst probably the most important cause of all is that in the land growths the extractive matter was of a highly resinous character, and in an atmosphere of low oxygen content protected the cellulose bodies, and led to the formation of solid products of degradations, and finally to carbon, these residues being luted together by the resin, and such hydrocarbons as are formed into coal.

"With seaweed, resins are absent, and the extractive matter consists of jelly-like bodies which offered no impediment to fermentation, and the action slowly proceeded until the whole mass was converted into gases and liquids."

It is difficult, of course, to say anything definite as to the question of the cost of producing and delivering petrol to the motorist, for with the exception of the 3d. tax and the 2d. commission to the agents, there is no charge that cannot be doubled or eliminated by a little genius in book-keeping.

Thus, freight to-day, 1913, stands at a figure in the order of 3½d. per gallon, and distribution is charged at 4½d. per gallon, which gives the following cost to the consumer if he is given the petrol itself for nothing :—

		s.	d.	
Overseas freight	.. ..	0	3½	per gallon.
Inland distribution	.. ..	0	4½	,,
Government tax	.. ..	0	3	,,
Agent's profit ..	.. ..	0	2	,,
		1	1	,,

That is to say, we have a charge of 1s. 1d. a gallon and still no petrol. It is, of course, all very well to say that freight was once 1½d., and that the 4½d. distribution probably includes a halfpenny for advertising. But any enterprising individual who tries to bring petrol from abroad in the same quantities, and to distribute it with the same thoroughness as is now needed to enable the motorist to replenish his tank in any remote district of England, Ireland, or Scotland, will be likely to find it difficult to effect much economy in the existing transaction.

In any case, motorists have demanded the convenience of being able to replenish their tanks in odd places, and have called into existence a vast vested interest in 2-gallon cans, and a complicated machinery of distribution, which is not lightly to be dismissed. It would, doubtless, be all the same to the distributors if they supplied benzol or alcohol instead of petrol, but the motorist is very

likely, in the long run, to have to pay as much for the convenience of being able to obtain it anywhere as he does now.

Those who have studied the report of the R.A.C. Petrol Committee will have realized that the supply companies do not encourage delivery in bulk as a means of reducing distribution charges, and individuals who can now "run round the corner" for their private supply of benzol should realize that they are in a privileged position by which they do well to profit while they may.

Benzol, as will be seen from the table of hydrocarbons of interest to the motorist, belongs to quite a different series from petrol. It is a spirit, and it is suitable for use in motor-cars, but it is a product of the destructive distillation of coal, and is not directly mined from the earth like petrol.

It is essentially a by-product; that is to say, real benzol is a spirit that is only produced where coal is distilled at high temperatures, such as are only employed for the primary purpose of manufacturing illuminating gas or metallurgical coke. If coal were distilled for the primary purpose of obtaining spirit, a lower temperature would be preferable on account of the greater yield. But, in this case, the oil produced is by nature a paraffin and not a benzene, and the spirit is, therefore, analogous to petrol and not to benzol.

It is mainly on the metallurgical coke ovens that motorists would have to rely for a supply of true benzol for use as another spirit in substitution for natural petrol. Many of these ovens, however, are not at present fitted with apparatus for the recovery of benzol from their tar residue, and opinions differ as to the magnitude of the supply of benzol that might be expected to be available in England were the inducement for its supply to motorists sufficient to bring it on to the market as a serious petrol substitute. From the second report of the R.A.C. Petrol Committee it would appear that 10 million gallons per annum might be so available from the recovery plants now in operation, and that about 30 million gallons might be recovered if all the coal now handled were treated in suitable apparatus.

An increase beyond this point would not primarily be governed by the demand for benzol as a motor spirit, except at an exaggerated price, since, even from the chief of its present sources, the spirit is only a by-product in the manufacture of metallurgical coke.

The market price of benzol has fluctuated enormously. In 1909 it touched 5½d. per gallon, and it has been as high as 1s. 1d. in casks at the makers'.

Used as a motor spirit, it is legally subject to the Government tax, which would, of course, be collected if the supply of benzol to motorists were

organized on a scale sufficient to make the cost of tax collection worth while. Thus, with the tax and the agent's fee, and the expenses of distribution on the same basis as petrol—viz. 3d. + 2d. + $4\frac{1}{2}$d. = $9\frac{1}{2}$d. per gallon—the price is not likely to be much below the present price of petrol if the manufacturer is to receive any sum that is likely to stimulate the installation of recovery ovens on a large scale.

Regarded as a fuel, benzol has the advantage of a superior thermal value when compared with petrol. In a Memorandum to the Petrol Committee by Mr. H. A. Morfey and Mr. J. E. Mitchell occurs the following interesting summary of the relative values :—

"With reference to the increase in mileage obtained by the use of benzol, it is only to be expected. The whole question is one of calorific power per pound of fuel. Assuming petrol to have a calorific value of 19,500 B.T.U. per lb., and 90's benzol to have a calorific value of 20,000 B.T.U. per lb., and taking petrol at $7\frac{1}{4}$ lbs. per gallon and benzol at 8·8 lbs. per gallon, this gives benzol an advantage of 20 per cent in calorific value over petrol per gallon, hence the increased mileage.

"Foul exhaust, valve sooting, carbon deposit in cylinders ; all these can be attributed to incomplete combustion. This is usually attributed to lack of air, hence the general advice to use more air with benzol than with petrol. Theoretically, however, benzol should not take more air

for combustion than petrol, and I attribute this call for extra air to benzol being delivered to the carburettor in nothing like so true a gaseous form as petrol. I am inclined to think, knowing how easily benzol vapour condenses, that serious condensation and assumption of the liquid state occurs in the induction-pipe in the case of benzol. It is, of course, at once apparent that if this is so the resulting explosion from such a charge can never ensure complete combustion, and in such case sooting, carbon deposit, foul exhaust, and actual waste of calorific value will ensue. The remedy for this, as we have found on stationary internal-combustion engines, is to have the carburettor as near the cylinders as possible. In the case of motor engines, I should suggest in addition to the shortest induction-pipe possible that this pipe be jacketed and warmed either by surrounding with warm water from the cylinder jackets or by by-passing a portion of the exhaust round it. In any case I have little doubt that sooting troubles and the like are entirely caused by the charge delivered to the cylinders being of a non-homogeneous character."

One of the most interesting distinctions between benzol and petrol may be illustrated by a comparison of their distillation curves as shown in the accompanying diagram. Petrol ordinarily commences to distil at or about 45° C.; 25 per cent of it is gasified at a temperature of 80° C.; 60 per cent or so passes over at 100° C.; and 90 per cent at 130° C. All the liquid must have been

distilled to dryness below 150° C., if the petrol in question is to be properly regarded as a benzine.

Benzol, on the other hand, commences to distil only when the temperature is 80° C., and it is this lack of more volatile fractions that causes it to be liable to give trouble when engines are started from the cold. Compared with petrol it is, however, a strikingly homogeneous spirit; the dis-

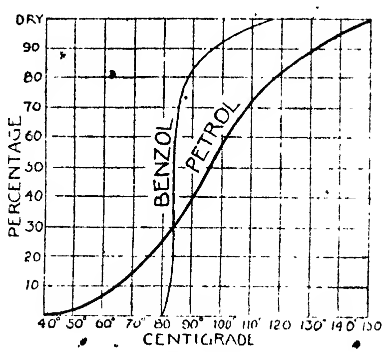


Chart illustrating a comparison of typical distillation curves for benzol and petrol. It will be observed that the higher fractions in the petrol begin to vaporize at a much lower temperature than benzol, which facilitates starting in cold weather, but that the benzol is, as a whole, a more homogeneous liquid, the greater part of it vaporizing at the same temperature.

tillation curve rises almost vertically, 85 per cent of the liquid distilling over at 90° C., while the entire quantity is gasified under 120° C.

Although the metallurgical coke ovens are commonly regarded as the main source of any possible large supply of benzol, it has been suggested, notably by an American, Mr. Doherty, that town gas might be "stripped" of its benzol for this purpose. Mr. Doherty, while on a visit

to England, was invited by Lord Montagu of Beaulieu to explain his views on the subject to a number of motorists assembled to meet him.

His proposition is one that, if it came to a head, would involve legislative action, for the benzol in town gas is an important constituent of its illuminating power, which at present has to be maintained at a certain standard that has been set by Act of Parliament. In order to attain this standard, a considerable quantity of the gas produced in this country has to be enriched by oil products.

It is apparent, therefore, that any serious proposal to take away the benzol naturally present in the gas would involve much discussion and no little opposition, particularly as the public is apt to have a deep-rooted suspicion of the *bona fides* of powerful corporations like the gas companies. Mr. Doherty himself is interested in gas companies in America, and his broaching of the subject before an English audience may be regarded as an item in an educational campaign.

The discussion in question was, however, altogether too nebulous to be really convincing one way or the other, but taken as the germ of an idea, which is how Lord Montagu referred to it, it certainly served the purpose of drawing interesting comment from some of those present, whose professions were more directly associated with the gas industry.

One of the most interesting of these remarks was to the effect that Manchester stands in the unique position of being able to do as it pleases in the matter of the quality of the gas that it supplies to its consumers. Manchester, it appears, has done its utmost to induce the poorer districts to make better use of their gas by employing incandescent burners, but, notwithstanding its efforts, 20 per cent of the gas supply is still consumed in flat-flame burners.

Mr. Doherty had estimated that not more than 5 per cent of the gas produced anywhere was consumed in this way, and had, therefore, argued that his proposal to strip the gas of benzol was virtually prevented from being realized in practice by the opposition or ignorance of this small minority.

Another interesting thing that came to light about Manchester was that some considerable time ago the Manchester Gas Company was called upon to supply gas to a firm that had established itself for the purpose of stripping it of benzol, in order that it might sell that spirit at 10s. per gallon to the aniline dye industry. At 10s. a gallon they doubtless made a handsome profit on the operation without worrying very much about other by-products, but the significant point in the episode was that the works closed down when the price of benzol began to fall below half a crown a gallon.

It was assumed by Mr. Doherty, and some

other speakers, that there could be no question as to the possibility of making a profit from the process of scrubbing town gas for the supply of benzol to motorists. It was not so apparent, however, that everyone in the room was in accord with this point of view. Mr. Butterfield put the matter this way. He assumed that removing the benzol would take away, perhaps, 7 per cent of the calorific value of the gas, and that it would, therefore, be necessary to supply the consumer with 7 per cent more gas at the same price.

A ton of coal yields, say, 10,000 cubic feet of gas at a works cost of, say, 10d. per 1000 cubic feet. It would be required, therefore, to supply 700 cubic feet extra with every 10,000 cubic feet, which would cost the works 7d. From the ton of coal or the 10,000 cubic feet of gas it would be possible to recover from 2 to 2½ gallons of benzol, and the cost of stripping the gas would have to be added to the cost of pumping the additional 7 per cent to the consumer. Mr. Butterfield estimated these charges as being roughly in the order of one shilling per ton of coal carbonized.

If the benzol recovered were two gallons only, the cost would be 6d. per gallon to the producer. It would, of course, be subject to a tax, like petrol, if supplied systematically on a large scale, and the distribution charges would amount to the same as they do at present with petrol. The tax on petrol is 3d. per gallon, and the distributing

charges claimed by the distributors of Shell spirit amount to 4½d. a gallon. The price of benzol scrubbed from town gas would thus be in the order of 1s. 1½d. a gallon before the producers saw any profit.

Figures of this character are largely a matter of book-keeping, and that which must most impress the student of the petrol problem is the impossibility of grasping in one comprehensive view the multitude of subsidiary factors that have an ever-changing relative importance in the case. The branches that now spread from the petroleum tree are legion, and the ramifications of coal-tar products are also exceedingly numerous. To concentrate upon one particular item such as petrol or benzol, and to attempt to deduce quantitative arguments from an arbitrary hypothesis, is to render oneself liable at the outset to make many serious errors.

Every motorist wants to see motor spirit reduced in price, but the condition that would be most likely to effect this is one that would cause the demand for petrol to become small as compared with the demand and the price realizable for other hydrocarbon products. If spirit could become a by-product in reality, something in fact that producers had to make and to get rid of in order to manufacture other more valuable commodities, then it might conceivably go down in price. But so long as motor spirit forms a pre-

dominating centre of attention on its own account in the world's fuel market, it is not likely to be very cheap.

Thus, so long as gas companies or metallurgical coke producers are urged to recover their benzol for the sake of the motorist, the willingness of their response is likely to be in direct measure to the magnitude of the price that the motorist is willing to pay for his fuel. On the other hand, were the gas stripped for other reasons, the motorist might very well come in for the benzol more or less at his own price. It was the opinion of some of those present that the metallurgical coke ovens, and not the gas plants, represented the proper place for benzol recovery. If it would pay anyone to recover, they said, it ought to pay the producers of metallurgical coke, and there still remain many ovens in England that are not run on the recovery principle. It is, of course, true that there has been some prejudice, both in this country and in America, against metallurgical coke from recovery ovens, but it has apparently been quite unfounded, and is now practically past.

A great deal more benzol than is at present available could be produced in this country if all the coke ovens introduced recovery apparatus, but anyone who has read the reports of the Fuel Committee and of the Petrol Substitutes Committee must have been somewhat struck by the lack of certainty on the part of some witnesses

as to the precise figure at which it pays to recover benzol, and it is very possibly owing to the uncertainty on this point that many firms hesitate to commit themselves to the capital outlay.

Reverting once more to the subject of stripping town gas, one speaker observed that the arguments put forward by those who advocated quantity as a substitute for quality were not altogether in accord with his own opinion. He considered, he said, that there was much evidence to show that gas below a certain calorific value was disproportionately inferior, and that above a certain value a slight increase in its quality made a very great deal of difference in its illuminating power.

Aspects of the case such as these are, of course, technical questions to be discussed by gas engineers, and if they collectively make out a good case to warrant a lower standard for town gas, then they are, of course, the proper people to try to get a Bill through Parliament to give effect to their views.

Whether or no they get the support of official motoring circles behind them in the matter must depend very largely on the assurance they are able to give that the benzol will be forthcoming under the conditions of revised legislation. It seems to me possible that if the gas standards were changed, it would still not necessarily liberate the benzol, because gas companies might

find it more profitable to alter the grade of coal employed rather than to put up plant for the purpose of artificially impoverishing their gas.

Indeed, the broad problems of obtaining gas and spirit from coal appear to me to be in some respects fundamentally in different categories. If spirit is the main consideration, the greatest yields come from low-temperature distillation, and the product is preferable inasmuch as it appears to belong to the paraffin series. On the contrary, high-temperature distillation yields most gas, and so it is exceedingly difficult to say where gas companies might find it pay to draw the line.

The low-temperature distillation of coal for the primary production of motor spirit, together with a smokeless solid fuel from the residue, has also been brought somewhat prominently to the fore by a syndicate interested in the operation of what is called the Del Monte system.

The Del Monte system is a process for the low-temperature (450° C.) distillation of coal (water is also admitted to the retorts), and it is important to recognize that in this respect it is fundamentally different from the high-temperature (1200° C.) processes employed in gasworks, and in the metallurgical coke ovens. It is fundamentally different, for two reasons—one being that the low temperature materially increases the quantity of tar obtained from a ton of oil, and, therefore, the quantity of spirit distilled from the tar, while the

other reason is that this spirit is "petrol," and not "benzol."

Benzol, as has often enough been shown, is a perfectly feasible motor spirit, but, on account of its odour and its higher initial boiling point, it can hardly be regarded as a preferable substitute for petrol. Moreover, the tar from which benzol is distilled is not susceptible, so far as is known, to "cracking," and it does not, therefore, lend itself to increased yields of synthetic spirit by catalytic reaction. This latter treatment has been successfully applied to the tar from the Del Monte retorts, and the fact may have an important bearing on its development.

Although petrol and benzol are both hydrocarbon compounds, they are extremely different both in composition and in qualities. It is a matter of consequence to avoid confusion between the two at all times, but especially so when discussing the liquid products resulting from the destructive distillation of coal. When coal is distilled at comparatively low temperatures the volatile portions condense into liquid hydrocarbons that are mainly of the paraffin series, to which the group known as "petrol" belongs. If the distillation of the coal is carried on at comparatively high temperatures, the paraffin vapours are apparently dissociated to form the entirely different type of molecular structure that characterizes the benzenes constituting commercial "benzol." (See page 204.)

At the present time, the distillation of coal is effected commercially on a large scale for two purposes—gas-making, and the manufacture of metallurgical coke. In the former case, to obtain the greatest volume of gas from a ton of coal is the main consideration, household coke being a by-product; in the latter case, the high-grade coke used in metal-melting furnaces and the like is the main issue, the gas being a by-product, from which it is possible to recover sulphate of ammonia and benzol from those plants that are equipped with suitable apparatus. In both cases, the temperature at which the coal is distilled is such as to produce tar containing the benzene series, and so it is, perhaps, only natural that the lay mind should associate all coal distillation processes with benzol production.

High temperatures are employed in the above operations, because they best suit the main purposes involved. Where the by-products are recovered, it is, therefore, inevitable that the portion suitable for motor spirit should be "benzol" and not petrol. By the same reasoning, benzol is essentially a by-product, and its supply is limited by the number of recovery ovens in operation.

Anyone seeking to make motor spirit as one of the main commercial products of coal distillation would have every reason to avoid high temperatures, and in avoiding high temperatures there

would be no tendency to generate the benzenes. On the contrary, the tar would naturally contain oil of the paraffin series, and its more volatile fractions would represent the commercial "petrol" of to-day.

No one had, apparently, hitherto deemed it wise to venture commercially on the production of petrol from coal, for the reason that the low price of the imported spirit left so little margin for profit. In 1913, however, the situation has seemed sufficiently promising to the promoters of the Del Monte system to encourage them to take a decisive step in this direction.

It must, of course, be borne in mind that the liquid fractions of the distillation of coal—which include ammoniacal liquor as well as petrol—do not represent the whole of the commercial issue. It would be impossible to make the process pay on these products alone if there were no market for the solid residue. By leaving from 8 to 10 per cent of volatile matter in the coke produced by the Del Monte process, it is anticipated that the system will yield a marketable smokeless fuel. Much depends, of course, on the commercial value of this commodity, as its ready and profitable sale necessarily affects the financial success of the undertaking and the price at which it is possible to sell the petrol.

The question of quantities and costs is one that it is almost impossible to analyse on

generalities. To the lay mind coal is just coal—to those who have to deal with it chemically it presents an infinite variety of grades.

The key to the situation, so far as future development on a large scale is concerned, lies in the sources of supply that are available. If the coal that now goes into the householder's grate can be commercially handled for the production of petrol, and the householder will accept the smokeless substitute with a smile at the right price, then all should be well.

Alcohol is a substitute for petrol that has been much advocated in different quarters on the grounds that its supply is limited only by the extent of the territory that is put under cultivation. Industrial alcohol is a product of the fermentation of starchy vegetable matter, potatoes, beet, molasses, maize, grain, sawdust and peat being among the substances that have either been employed or suggested for its preparation.

The grain is mashed, malted, fermented, distilled and denatured: the last-named process being a legal necessity in order to render the spirit undrinkable. Briefly stated, damp, starchy grain germinates in a hot-house, producing diastase which converts the starch into malt sugar. The diastase in the malt similarly converts the "mash" into a sugar solution. Yeast sown in the malt sugar solution splits it up into alcohol and carbon dioxide. The alcohol is then separated from

the waste by distillation; the primary product "ethyl alcohol" being accompanied by secondary products such as fusel oil, ethers, acetic acid, aldehydes and furfural. Wood naphtha is the common denaturant employed to render industrial alcohol unfit to drink.

The strongest argument in favour of alcohol as a petrol substitute is undoubtedly that which draws attention to the broad principle of its unlimited supply and the possibility of growing it at home. Alcohol, as produced, say, from maize, is a ready means of converting the sun's energy, year by year, into a convenient form for man's use, and on the assumption that the earth's contents of coal and petroleum are limited, the general idea of encouraging the use of alcohol for industrial purposes presents itself for study as an economic question.

To England, which is so much isolated from her sources of liquid fuel supply, the problem might be supposed to appeal with great force, but no very satisfactory evidence has yet been adduced to show that we could grow cheap alcohol within our own shores in sufficient quantities to satisfy the demand at a reasonable price. The climate does not suit the growing of grain on the necessary scale, and agricultural considerations render it very unlikely that potatoes would be grown for sale at a price that would make their conversion into alcohol a commercial proposition.

If one obtained twenty gallons of alcohol from a ton of potatoes, the spirit would still cost 1s. a gallon if the farmer were paid only £1 a ton for his potatoes and the conversion process cost nothing. If potatoes were worth growing at all in this country, or even in Ireland, they should surely be worth more than £1 per ton, and, as we have seen, any spirit that is likely to cost 1s. per gallon at the factory is most unlikely to reach the motorist's petrol tank at much below the present price of petrol.

The problem of introducing alcohol as a petrol substitute is in any case one that presents particular difficulties in England owing to the legal position. Thus, the law demands that alcohol must be denatured, that is to say rendered undrinkable, by a process that is not only comparatively costly in respect to the materials employed, but is also expensive in the manner of its operation under Government supervision. The present price of methylated spirit is a sufficient indication of the nature of those charges. Pure alcohol is, of course, subjected to an enormous tax. Thus, even assuming the suitability of the material, it would still be unavailable for use unless very radical changes of a legislative order were brought about. Until the fuel problem becomes more than ordinarily acute, therefore, it is not to be expected that any serious move will be made in the direction of cultivating industrial alcohol.

Industrial alcohol is cultivated in Germany under the encouragement of the German Government, in order that some of the population may be supported on great tracts of land that otherwise would be barren. Industrial alcohol is used for many purposes in Germany, and its use is encouraged by the State, which enables it to be sold at less than cost price. It seems somewhat significant, however, that among the purposes for which it is applied, the driving of motor-cars does *not* figure pre-eminently.

Peat has often been suggested as a source of alcohol, and also for that matter as a source of synthetic petrol, but it is doubtful whether this substance could be handled economically for either purpose.

If alcohol were grown in tropical climates in the form of maize, or were produced from the refuse of the lumber-yards in the great timber regions, it might be written down at an apparently enticing price per gallon, but then we are again in the unfortunate predicament of having to superimpose freight charges which, under similar circumstances, would not be less than at present obtain for petrol.

In a paper read before the Institution of Automobile Engineers, Dr. W. R. Ormandy has pointed out that although methylated spirits has a thermal value of only 11,600 B.T.U. per pound as compared with about 20,000 B.T.U. per pound for petrol, the

quantity of air required to effect perfect combustion with alcohol is very much less than is necessary for either petrol or benzol, and that, in consequence, a cylinder full of perfect mixture possesses approximately the same heat value for all of the three fuels named.

Methylated spirits requires about ten times as much heat in the carburettor as petrol, and until the intake jacket is about 160° F. steady running of the engine is seldom obtained.

Methylated spirits may be mixed with benzol.

CHAPTER XIII

THE CARBURETTOR

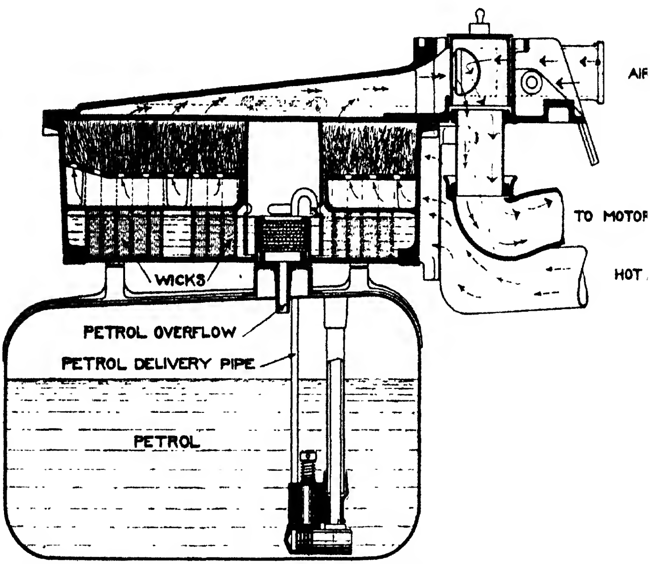
ALTHOUGH petrol is a very volatile liquid, the problem of regulating its evaporation and mixing it with air for use in motor-car engines has taxed the ingenuity of many inventors. The process of mixing petrol vapour with air is called carburation, and the apparatus that accomplishes this purpose on a car is the carburettor.

There are three main classes into which carburettors may be divided. The first and simplest is the surface carburettor, in which the air is drawn through the upper part of the petrol tank, where it automatically comes into contact with the surface of the petrol contained therein. In some cases the efficacy of this crude arrangement was increased by splashing the liquid by means of revolving paddles, but in either form the simple surface carburettor is now to all intents and purposes obsolete.

Another method of artificially increasing the surface is to employ a wick, but the wick carburettor properly constitutes a class of its own. The only notable example of the wick carburettor

at present in use is the Lanchester carburettor on the Lanchester cars.

In the wick carburettor, the principle is similar to that of the surface carburettor, but instead of increasing the saturation of the air by splashing the liquid, the petrol is encouraged to ascend a



The Lanchester wick carburettor, of which the above drawing is a diagrammatic section, is fitted immediately over the petrol tank. The roots of the wicks are tightly packed in perforated tubes, which are immersed in a reservoir that is kept full of petrol by the action of a pump. The petrol is drawn up the wicks by capillary action and vaporizes in the mixing chamber. Air is admitted as shown by the arrows on the drawing.

wick by capillary action, which, by bringing a relatively large surface of the liquid into contact with the air, directly increases the carburation.

The third class of carburettor is the spray-jet type, and depends for its action on the automatic atomization of a fluid that is forced into the

atmosphere through a very fine nozzle. The petrol is sprayed into the intake passage, through which the air rushes into the working cylinder during the suction stroke of the piston. The blast of air itself tends further to subdivide the fluid, which enters the cylinder more as a vapour than as a spray, and in any case the unvaporized petrol is immediately evaporated by the heat of the cylinder walls, once it has entered the combustion chamber.

The spray-jet carburettor of one kind or another is universally employed on modern cars, but the variety of such carburettors is legion. At one time, the spray jet on some machines was fed directly from the petrol tank without any special system of automatic regulation, but the method that has survived all others in this matter is that embodied in what is known as the float-feed carburettor.

In this device the petrol from the tank enters a small chamber containing a hollow brass drum that is buoyant in petrol. This float controls a needle valve in the admission pipe, and when the petrol in the float chamber has risen to a predetermined height, the needle valve automatically shuts off any further supply. By this simple contrivance a constant level of the petrol in the float chamber is maintained.

A passage from the float chamber communicates with the jet, and the height of the jet corresponds

with the level of the petrol in the float chamber, so that while the petrol may perhaps form a tiny bead on the top of the jet it will not of its own accord overflow therefrom.

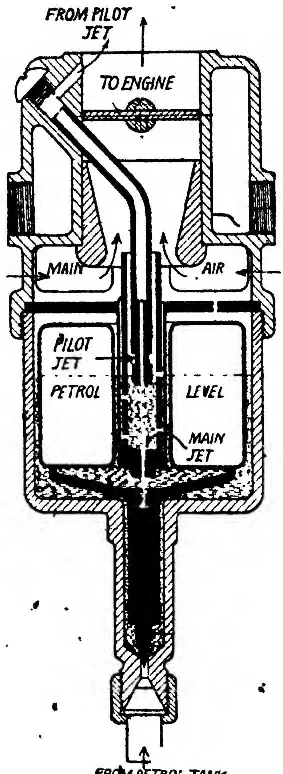
The least difference of atmospheric pressure in the jet chamber and in the top part of the float chamber suffices to disturb this equilibrium and to cause petrol to spray from the jet. The pressure in the float chamber is always that of the external atmosphere, because there is a small vent hole in the lid, but the pressure in the jet passage depends on the flow of air therethrough, and is always slightly below that of the outside atmosphere so long as the engine is working.

The amount of the "suction" in the jet passage depends on the conditions under which the engine is operating. When running fast on an open throttle, the suction of the engine causes a considerable lowering of the pressure in the induction pipe, but when the engine is running slowly and the throttle is partially closed, the depression around the jet is less in amount.

It is apparent, therefore, that, even in its simplest form, the jet of a spray carburettor would be automatically subjected to a variable suction effect depending more or less directly upon the running of the engine. It would, therefore, tend in some measure to adjust its supply of petrol to the requirements of the engine.

It is towards the improvement and refinement

of this automatic regulation of the mixture of petrol and air in accordance with the requirements



The Ware carburettor has a low-level jet feeding into an annular sump. The inner tube of this chamber is perforated so as to admit petrol to the narrow annulus between it and the outer wall. In this annulus the petrol rises slightly by capillary action, and in so doing, it reaches one of the other perforations that is for the time being above the level of the petrol in the central tube. Through this perforation it is sprayed back again into the central tube when the mixing chamber is subjected to suction by the opening of the throttle, and in this manner the annulus serves temporarily as a high capacity jet when the throttle is opened after a period of slow-speed running. In order to facilitate easy starting on a nearly closed throttle, a pilot jet is arranged as shown in the drawing.

of the engine that carburettor designers of late years have in the main been working. The complete quantitative solution of the problem

presents exceptional difficulty, as can readily be seen from a brief consideration of the conditions under which an engine works in practice.

Sometimes the motor may be turning fast on a light load and a partially closed throttle : at other times it may be turning more slowly against a heavy load on an open throttle. The quantity of air drawn into the cylinders in a given interval of time may conceivably be the same for both conditions, but it is not by any means equally certain that the ratio of petrol to air should be the same in the two cases. A better effect, for instance, may perhaps be obtained with the slow-speed heavy load running, if the mixture is richer in petrol, than when the engine is running fast on a light load. This is not necessarily always the case, but it may be so in some instances, and those who seek to compensate for this effect commonly construct their carburettors so that the size of the jet orifice is mechanically regulated by the throttle opening.

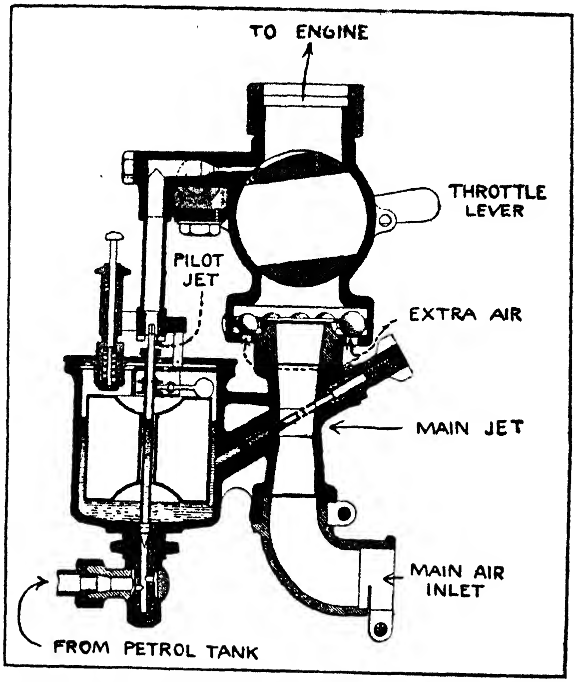
There is also to be considered the condition brought about by an increasing engine speed *per se*. In general, its effect is to produce a disproportionately rich mixture at high speeds, because the superior velocity of the air through the jet passage has a more decided injector action upon the jet than is the case at low velocities where the spraying is more directly due to the general reduction of the pressure in the jet passage.

Indeed, it is common practice to fit a choke tube in the vicinity of the jet, so that by contracting the bore of the intake pipe at that point the velocity may be increased locally to a value sufficient to ensure injector action, even when the engine is running quite slowly. The development of engines that are capable of running very slowly indeed, and particularly the development of engines that are easy to start, has necessitated this feature in carburettor construction, and as this principle produces a rich mixture it is self-evident that there will necessarily be a surplus of petrol in the mixture when the motor is running fast.

A carburettor thus constructed to give a fully rich mixture at very low speeds is, therefore, necessarily uneconomical with its fuel at high speeds unless the effect is compensated, and designers of carburettors have, therefore, sought to make the correction by introducing some form of automatic auxiliary air valve that is controlled solely by the suction in the mixing chamber.

The object of such a valve is to admit atmospheric air direct to the induction pipe at some point between the jet and the cylinder of the engine, so that the air thus admitted dilutes the rich mixture formed in the jet passage. It is apparent that this extra air valve will open indiscriminately whether the suction in the mixing chamber is due to slow-speed running on a heavy

load and open throttle, or to high speed running on a light load and partially closed throttle. If the jet orifice is the same in both cases, the additional air may either be superfluous or inadequate,



The "G. A." carburettor has a single main jet situated below the petrol level of the float chamber, but there is a tubular extension to the jet in which the petrol rises to the proper level when the engine is at rest. This extension also serves as a pilot jet for starting and accelerating as it gives a momentarily increased rate of discharge. Extra air is admitted through orifices that are normally closed by steel bolts. These orifices are of different sizes and the balls are of different weights. A pilot jet to facilitate starting on an almost closed throttle is obtained by using a hollow needle-valve stem in the float chamber.

according to the original setting of the jet, and it is for this reason that the jet orifice is frequently interconnected with the throttle, even where extra air valves are also used.

These principles of regulation are sometimes referred to as compensation for load and compensation for speed, the former relating to the interconnection of the jet with the throttle and the latter to the automatic entry of the additional air. Some carburettors have either the one or the other and some have both.

A modification in design that to some extent combines these principles in a common moving member is one in which the effective bore of the passage itself is controlled by the suction in the induction pipe.

A true variable choke tube acts in principle as a throttle valve, and may be so constructed as completely to close the jet passage when the engine is at rest. It is possible so to arrange the throttle itself as to afford a variable choke, as, for instance, when the throttle consists of a double-ported sleeve mounted concentrically with the jet. In such a design, the jet chamber is isolated from the induction pipe and from the atmosphere when the throttle is closed. As the throttle opens, the orifice communicating with the induction enlarges at the same rate as the orifice communicating with the atmosphere. The velocity through these two orifices is substantially equal at any moment, and for a given throttle opening it depends on the speed of the engine.

The White and Poppe carburettor is an instance of this principle in conjunction with the variable

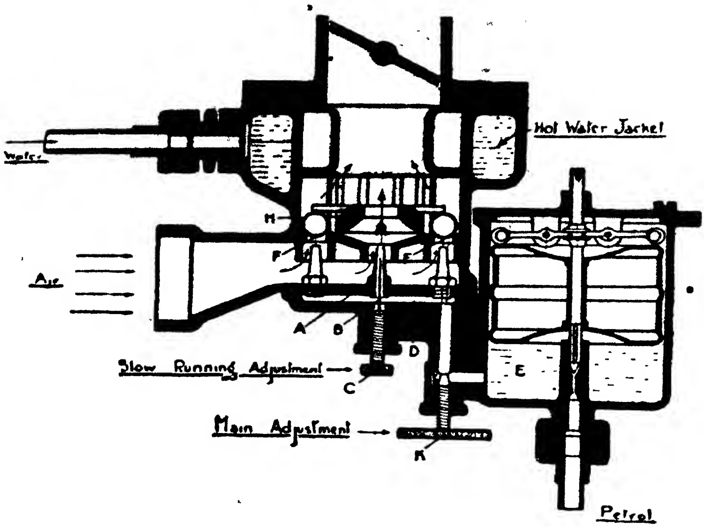
jet. As the above-described type of throttle is opened in this carburettor, the jet orifice is enlarged, thereby compensating for increasing load.

It is important to recognize the significance of the isolation of the jet chamber from both the atmosphere and the induction pipe. If there is a throttle on the engine side of the jet only, the jet is virtually exposed to the outside atmosphere, and everything will depend upon the size of the choke tube surrounding the jet as to the engine speed at which it will be possible to obtain a proper spray of petrol. On the other hand, if the throttle valve were on the atmospheric side of the jet, the jet itself would be subjected to the direct suction of the engine, and with the throttle valve closed there would be a great waste of petrol. A throttle on both sides of the jet chamber serves the purpose of an infinitely variable choke tube, and to that extent avoids the necessity of using an automatic auxiliary air valve for the admission of the requisite volume of air at high speeds and loads. At the same time, however, the variable choke will not afford an automatic regulation of the mixture unless it is interconnected with a variable jet orifice, for an increasing choke with a constant jet would provide too weak a mixture on full open throttle, except perhaps when the engine might be running unusually fast.

While this method of arranging the throttle so as to provide a variable choke seems to be the

simplest and most direct solution to this particular problem, there are many carburettors that have an ordinary throttle on the engine side of the jet chamber, and introduce into the design of the carburettor itself some form of sliding member that automatically regulates the bore of the choke and the effective size of the jet simultaneously.

As these automatic chokes are controlled either by the action of a spring or by their own weight, it is apparent that a given area of choke passage will correspond to a given suction, no matter how that suction may be obtained. Thus, for a given throttle opening, the automatic choke will maintain a constant velocity through the choke passage by increasing its area in accordance with the requirements determined by the speed of the engine. In order to maintain a constant richness of mixture, it is apparent that the variable choke must be interconnected with a variable jet, so that the enlargement of the choke may be accompanied by a corresponding enlargement of the jet orifice. Similarly for increase of load at a constant engine speed, if the opening of the throttle causes the engine to increase the suction in the jet chamber, the variable choke will open up the effective air passage and at the same time enlarge the orifice of the jet. It will be observed that the automatic variable choke differs in principle from the choke that is varied positively by the throttle opening, because it tends to maintain a constant suction



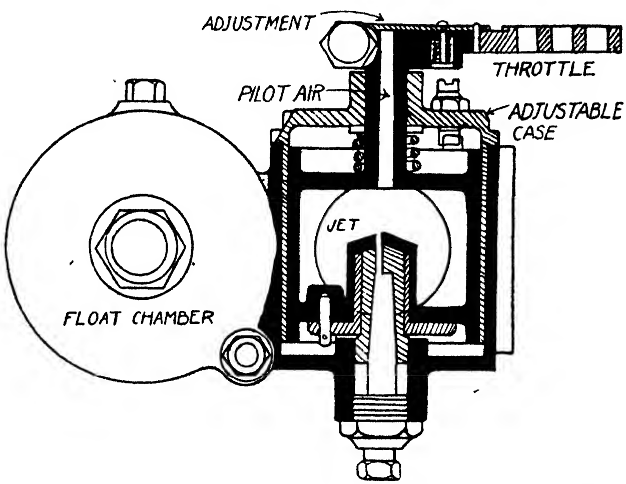
The Daimler carburettor is an example of the multiple-jet type in which the jet chokes are normally closed by steel balls. It has seven jets and two adjustments. Six of the jets are arranged in a ring, the seventh is in the centre The central jet is provided with a needle-valve, B, under the control of an adjustment-screw, C, the object of which is to set the slow running of the engine. All the jets are supplied with petrol from the common chamber, D, which is in communication with the float-chamber, E, by a passage that is under the control of a main adjustment-screw, K. The central jet discharges into a central jet-chamber having direct communication with the induction-pipe through the main throttle-valve. The six other jets discharge into an annular mixing-chamber, each through its own separate passage, which is normally closed by a steel ball. In addition to the six balls that close the passage into which the jets discharge there are six similar balls, normally closing similar passages, through which pure air only can pass. In addition to their own weight, the balls are held down on their seats by a light cage or spider-shaped weight, marked H in the drawing. When running slowly the suction is concentrated on the central jet, and the central orifice supplies the necessary mixture of petrol and air. As the suction increases, all the balls are lifted off their seats, and the cage causes them to lift equally. The six jets thus come simultaneously into action, and the greater the suction the greater is the lift, the greater also is the discharge of petrol and the intake of air. A very slight movement of the screw, K, suffices to restrict or enlarge the supply of petrol from the float-chamber to the common jet-chamber. Ordinarily, however, this screw should not need adjustment after it has been set at the works. It is important, also, that the jets should not be altered, as they are of equal size and bore, and the successful operation of the carburettor depends on this condition. Although there are twelve balls and twelve orifices, the cage has only eleven spider-like arms, and it is important that when this cage is removed for any purpose to remember, when replacing it, to leave the vacant space over one of the jet-passages and not over one of the air-holes. The object of this is to facilitate quick picking up. It is of no consequence which jet is thus left uncovered, but it is of vital importance that it should be a jet-passage and not merely an air-passage, otherwise the engine is likely to be starved if the throttle is quickly opened.

on the jet with increasing engine revolutions, and thus to supply a uniform strength of mixture throughout the speed range. The choke that is positively interconnected with the throttle delivers a strength of mixture that depends on the suction effect produced by different engine speeds, and, in general, the tendency of such a system is to produce an over-rich mixture at high speeds.

This tendency of the mixture to increase in richness with increasing velocities of air flow through the choke is, as has been explained, one of the fundamental difficulties in effecting proper carburation at all engine speeds. If anything, it is possible to run most engines better on a weaker mixture at high speeds, and from the standpoint of economy alone there is sufficient reason why the mixture should, at any rate, not be stronger. In making compensating arrangements to overcome this difficulty, designers of carburettors have naturally had in mind the desirability of avoiding as far as possible the use of moving parts, which are always potentially liable to give trouble.

One of the most ingenious systems devised for counteracting the increasing richness of the mixture at high velocities is that invented by M. Baverey, who, by the combination of two jets, succeeded in maintaining a uniform strength of mixture throughout the speed range without the use of any moving member at all. Taking as his

starting-point the established fact that a jet in a fixed choke delivers an increasing *ratio* of petrol to air with increasing velocities of air flow through the choke, he proceeded to introduce a second jet having precisely the opposite characteristics. The simultaneous action of both jets thus neutralized



The White and Poppe carburettor has its jet surrounded by a double-ported rotary throttle that forms a variable choke. The jet orifice is eccentric, and is partially covered by a cap that moves with the throttle. As the throttle opens, the jet orifice is enlarged. The throttle moves in an adjustable case, so that the relationship between the throttle opening and jet orifice can be set to suit any particular engine. The throttle stem is hollow, to admit air, and its upper orifice is covered by an adjustable plate.

each other and maintained a constant strength of mixture.

In Baverey's system, the first jet was similar to that used in any ordinary carburettor, being directly connected to the float chamber. The second jet, however, was not directly connected to the float chamber, but obtained its supply from

a small tubular reservoir that was open to the atmosphere. This secondary reservoir was itself fed from the float-feed chamber through a fixed small orifice, which at all times delivers petrol under a constant head, and, therefore, at a constant rate quite irrespective of the operation of the engine. If the engine is not running at all, the small tubular reservoir merely fills up to the level of the petrol in the float chamber, and the action ceases.

As the suction of the engine cannot increase the rate of flow from the second jet beyond the rate at which its small reservoir is supplied with petrol from the float chamber, which is a constant quantity, the *ratio* of petrol to air necessarily diminishes at high engine speeds when the air flow increases in quantity.

The only time when an abnormal discharge of petrol can be obtained from the second jet is immediately after a period of comparatively slow running. When running very slowly, the discharge from the second jet may take place at a slower rate than the supply to its reservoir, consequently this reservoir will temporarily fill with petrol. A sudden opening of the throttle will then produce a sudden suction upon the second jet, and for a moment or two its reservoir will act like an ordinary feed chamber; that is to say, it will discharge its contents at an abnormally high rate. As, however, the sudden opening of the

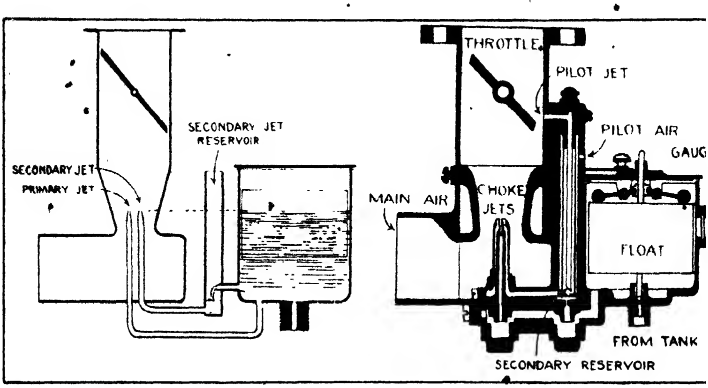
throttle represents conditions of engine operation that render a temporary increase in the richness of the mixture very desirable. this peculiarity of the system is distinctly an advantage rather than otherwise.

The successful action of a carburettor in practice depends on more factors than those that merely relate to the theoretical compensation of the adverse tendencies that hitherto have been described. One of the most important qualities of a carburettor, for instance, is that it shall enable the engine to pick up rapidly, which process is associated with the sudden opening of the throttle. Owing to the fact that there is a certain amount of sluggishness even in the response of the flow of liquid to sudden changes of pressure, it is by no means unusual for the theoretically perfect system to fail at this critical moment solely because the practical requirements are temporarily abnormal. It is because the above-described Baverey system combines in this way the requirements of prosaic theory with one of the most important practical idiosyncrasies of the motor-car engine, that it is not only a very interesting process, but also one that is very successful in practice, the system being that employed in the carburettor known as the Zenith.

In several carburettors, the effect of a variable jet orifice is obtained by the use of a series of jets, each having a fixed orifice. In these designs

the control is such that the jets come into operation consecutively as the throttle is opened.

Sometimes a carburettor has two jets so arranged that the engine runs exclusively on one or on the other. In such designs, one of the jets



The Zenith carburettor, of which the above drawings show the principle diagrammatically and the construction of the carburettor itself, is designed to maintain a constant richness of mixture without the use of moving mechanical parts. There are two jets. The primary jet draws its supply direct from the float chamber in the usual way. The secondary jet draws its supply from a subsidiary small reservoir that is open to the atmosphere. This reservoir is fed direct from the float chamber, but as it is open to the atmosphere, the rate at which petrol enters it is fixed by the size of the feed pipe thereto, and is not in any way influenced by the suction on the secondary jet itself. The secondary jet cannot, therefore, draw more than a given quantity of petrol in a given time, and the rate of its discharge being constant, its contribution to the strength of the mixture represents a *diminishing ratio* of petrol to air when the air velocity through the carburettor is high. On the other hand, the primary jet, being directly connected to the float chamber, increases its discharge as the suction in the mixing chamber increases, and it is common property of such a jet thus arranged to contribute an *increasing ratio* of petrol to air as the air speed through the choke increases. The effects of the primary and secondary jets are thus diametrically opposite, and if properly proportioned, they neutralize one another so as to maintain a constant strength of mixture. In the actual construction of the carburettor, the primary and secondary jets are concentric. A subsidiary advantage of the secondary jet reservoir, which naturally fills up to the level of the float chamber when the engine is at rest or running very slowly, is, that it enables the secondary jet to increase its rate of discharge momentarily, when the throttle is suddenly opened, and it is on such occasions that a temporary increase in the delivery is desirable. For the purposes of easy starting, a pilot jet is arranged in the vicinity of the throttle, and it draws its supply from the reservoir. The engine should be started with the throttle nearly closed.

is, of course, larger than the other. A modification of this principle is to arrange for the engine to use one jet only when it is running slowly, and to bring other jets successively and collectively into use as the throttle is opened.

As the essential feature of the multiple-jet carburettor is the use of many jets instead of one jet, and as the salient point in this arrangement is to provide a variable jet orifice, the remarks that have already been made upon the subject of the variable jet apply equally to the carburettors in which several jets replace the single variable jet.

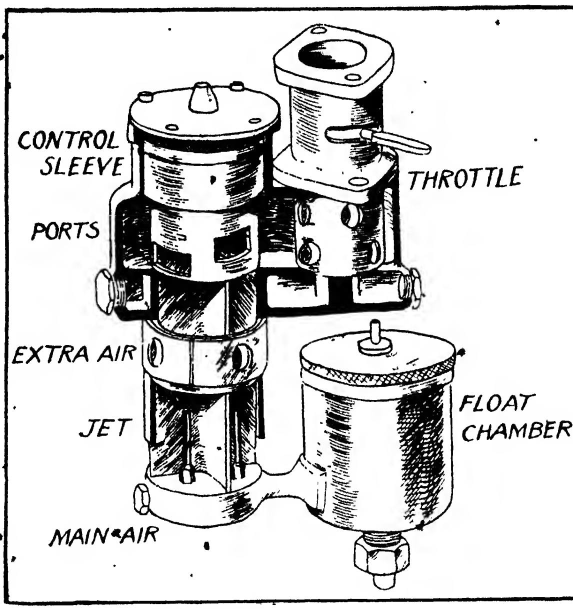
In some cases, each of the several jets is contained in its own choke, the passage through which is either regulated by the suction of the engine or by the positive control of the throttle.

By way of concluding this chapter, it may be of interest to some readers to recall the famous Maybach litigation, as it was the first and almost the only automobile patent case of general importance that has been fought in the English courts. Its unique position in the history of motoring is the more remarkable, considering the complete newness of the motor-car as a piece of machinery and the many hundreds of patents that have been filed for its "improvement."

Among these, Maybach's related to the invention of a spray carburettor, and the owners—the British Motor Traction Co.—claimed it to be a basic patent covering the float-feed regulation of the petrol supply to the jet, which was then and still is the most satisfactory method of working.

Two actions were fought. The first was that of the British Motor Traction Co. against

J. V. Sherrin, which was tried before Mr. Justice Kekewich and resulted in favour of the plaintiffs. The second was brought by the same plaintiffs against Charles Friswell. It was tried before Mr. Justice Farwell, and resulted in favour of



The Smith carburettor, of which the above drawing is a perspective sectional sketch, contains four jets of different sizes, each of which is isolated in its own choke tube. The upper ends of these passages are covered by a sliding sleeve containing ports. The movement of the sleeve is controlled by the suction of the engine, and as the suction increases so do the ports uncover more of the jet passages. There is also an adjustable series of ports admitting extra air above the jets.

the defence. The full reports of these cases will be found in the June and August issues of the *Automotor Journal* for the year 1901.

It was made very clear by the judge in the second case that the decision in the first case

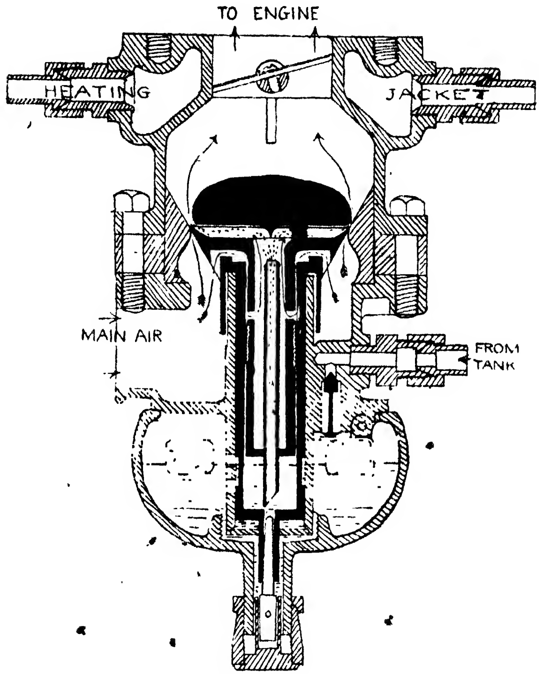
was essentially a consequence of the evidence brought into court. The second case, which was much better handled for the defence by Mr. Thomas Terrell, brought to light several points of first-class importance, which resulted in the defeat of the Maybach patents.

Prior to this case, it had commonly been assumed that the Maybach patent was for the float-feed regulation of the petrol supply to the jet. It transpired in the course of the evidence, however, that this was not at all what Maybach really thought he had invented. What he thought he had really invented was embodied in his original claim, which ran :—

"The method of producing an explosive mixture in hydrocarbon engines, consisting in sucking liquid hydrocarbon by the air sucked by the working piston substantially as described."

It is apparent from this that Maybach thought he was inventing the principle of carburation by the spraying of petrol into the intake pipe. Finding, presumably, that he could not support this contention, he amended out his original first claim, so that the patent, when it came into court, had as its first claim what formerly was the second clause, and in which was the following passage : "A swimmer valve for the purpose of maintaining the level of the hydrocarbon within the basin at a constant height."

It was held by the judge that Maybach's patent was essentially a patent for a method or process for producing the explosive mixture in



The Stewart carburettor, of which the above drawing is a sectional sketch, comprises an automatic variable choke with a variable jet orifice controlled by the moving member. The moving member is shown black in the above drawing. The suction in the mixing chamber raises it, thus increasing the area of the annular passage between it and the carburettor casing. At the same time, this action withdraws the lower end of the tube from a tapered spigot and thus enlarges the orifice of the petrol jet. When the engine is at rest, petrol rises inside the moving member to the level of the petrol in the float chamber. Under such conditions, a pilot tube has its lower end immersed so as to facilitate starting.

explosion engines, and, to be Maybach, the oil must be sucked out of the oil tube, at any rate partly, by the injector action of air rushing over or round the end of it. If it is sucked out merely

by suction taking place in accordance with the laws enunciated above, and by distribution of pressure, produced by suction between the air valve and the oil tube, then it is not Maybach.

Many patents were put into court by the defendants as anticipations of Maybach's patent, but those chiefly relied upon were the patents of Wilkinson and Butler.

George Wilkinson invented substantially the same thing as Maybach, but he had allowed his patent to lapse.

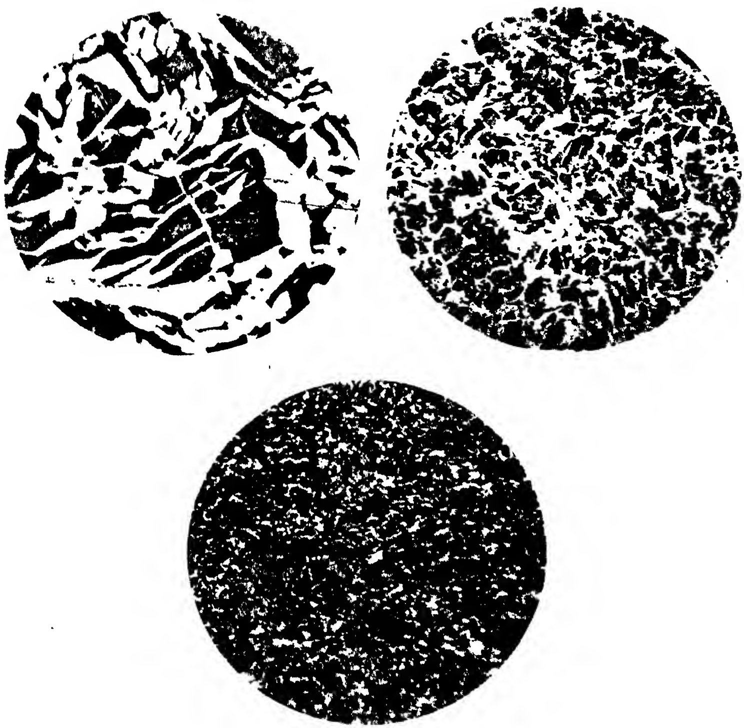
Maybach's patent was No. 16072, dated 25 August, 1893.

CHAPTER XIV

THE MATERIALS OF WHICH CARS ARE MADE

MOTORISTS are told a great deal about the accuracy that is attained in modern car construction, but few car owners have any opportunity of learning even a little about the materials of which their cars are made. Nevertheless, these same materials are liable to far more internal irregularity than even indifferent exterior workmanship would show, and the interesting point about this is that lack of uniformity passes entirely unsuspected until the faulty part fails in use. It is easy enough to test a piece of steel to destruction by fixing its ends between the jaws of a vice and pulling upon it until it parts in two, but aside altogether from any question of utility or otherwise of the test itself, there is always the doubt whether other pieces of supposedly similar material are indeed the same.

It is difficult even for the scientific, let alone the lay, mind to grasp the truly extraordinary divergence that can occur in the quality of a piece of material merely as the result of heating it in a furnace or cooling it in a bath. The specimen that has been so treated in a manner that har-



THREE MICRO-PHOTOGRAPHS, SHOWING A SPECK OF STEEL MAGNIFIED 300 DIAMETERS

The difference in the appearance illustrates the effect of "cooking" the steel in an oven. The first micrograph shows the steel as it is received from the forge, the second is the same steel after heat treatment and quenching in oil. The third micrograph was taken after final tempering. The fine, close-grained homogeneity of the structure in the third micrograph, shows a steel that is very much stronger to resist shock and fatigue than the coarsely angular or crystalline state of the metal in the first micrograph. These micrographs were all obtained in the laboratories of the Daimler Co., where the heat treatment of the steel used in the Daimler cars is regularly practised, and they are reproduced from the Author's "Notes on the Materials of Motor-car Construction."

monizes with its nature is not only a little stronger, but many times stronger, than one that has either not been treated at all, or has been improperly treated by making it too hot, or by not keeping it hot long enough, or by cooling it too quickly, or by not cooling it quickly enough. It is difficult to realize the wonderful difference between the natures of two such pieces of metal, because the naked eye can distinguish no difference whatever, and even a chemical analysis only serves to show that, so far as composition is concerned, the two specimens remain exactly the same.

Moreover, not only do the eye and the test tube fail to show any difference, but some of the more ordinary tests, such as stretching the piece until it breaks, also fail to give adequate evidence of the superiority that the properly treated specimen undoubtedly displays under the practical conditions of everyday use. It not infrequently happens that a piece of material, which has been passed as completely satisfactory by the standard of ordinary tests for mere direct strength to oppose a direct pull, subsequently breaks down while working under a load that is well within the limit that the material is, according to the tests, capable of withstanding.

In these cases, the material is said to have failed from fatigue, and when one considers the manner in which motor-cars are used, how they are always starting and stopping and being jolted about

over rough roads, it becomes fairly self-evident that the one quality required of all parts of a car is that of endurance, in other words, that they should not give way merely because they get tired of doing their work. There is small difficulty nowadays about finding a specimen piece of steel that will withstand enormous stresses and last for an unlimited time in use provided the working load is a reasonably small fraction of the maximum load that it can withstand. The difficulty arises when the same high qualities are expected of *every* individual member of a large batch of parts that have been made commercially.

The proviso mentioned above, that a metal must not be stressed beyond its power of recovery, is important. It is very clear, for instance, that a piece of steel must never be so stressed that it is *permanently* distorted, but if it is only strained a small amount so that it always recovers by virtue of its own natural elasticity, the strain may be repeated indefinitely without evil consequences, provided that the metal was properly treated to withstand them in the first instance. All materials are more or less elastic, and by elastic is meant the power of recovering its original shape after being deflected, and not merely the ability to be stretched a great deal like india-rubber. Some of the very best steels, which are apparently rigid, are, in reality, much more elastic than commonplace objects like rubber bands that seem superficially

PHASES IN THE PREPARATION OF THE MATERIALS FOR MOTOR-CAR CONSTRUCTION AT THE DAIMLER WORKS, COVENTRY

The upper view shows the charging of a cupola with raw metal, which when melted will be used for casting. The second view shows molten steel being poured from the "Stock" converter. The third view shows molten metal being poured into the sand mould to produce a casting. The bottom view illustrates a crank-shaft forging in the rough, being removed from the oven where it has been "cooked" for the purpose of putting its molecular structure into the best condition to withstand shock and fatigue. It is now being transferred to an oil-tank for cooling purposes. The above views are taken from the Author's "Notes on Materials of Motor car Construction."

to be possessed of the power of stretching and recovery to a much higher degree. Those who have the misfortune to use elastic bands very frequently, however, will readily agree that there is an early limit to the number of times that such things can be used before they show signs of a permanent stretch. If one pictures for a moment a corresponding state of things occurring in the motor-car, its condition after a few months' use would be, to say the least of it, grotesque.

When the explosion occurs in the cylinder of an engine, more or less of a blow is thereby struck on the top of the piston. The piston is hinged to the connecting-rod by a pin, which the shock tries to shear in two. The connecting-rod forms a column, or strut, between the crank-shaft and the piston, and the explosion tries to double up that member under compression. If it gives way a little, the force tends to exaggerate the bending, and thus obtains a better opportunity of breaking the rod. When the crank has moved away from its dead centre or vertical position, the force on the piston is transmitted through the leverage of the crank and becomes torsion, or a twisting effort on the shaft, which twists a little *in* itself while it turns round in its bearings as a whole. In this way, the stress is transmitted from one end of the chassis to the other; it passes through the teeth of the gear-wheels, and finally it arrives on the tread

of the tyres where they take their grip of the road.

To an infinitesimally small extent, which is quite unobservable to the eye, do all the various parts of the car "give" under each of these repeated impulses from the engine, and it is alone due to their power of instantaneous and complete recovery that the machinery as a whole lasts as long as it does. But for this comparatively perfect elasticity, the motor-car would, metaphorically speaking, soon be in the condition of the much-used elastic band; only, as the conditions of operation are such that a nicety of fit is essential to continuance of work, the immediate effect of any permanent distortion is a complete breakdown either of that part or of those adjacent to it, and so any general extension of permanent distortion throughout the car is impossible.

Now, this repeated stressing of the parts to a minute extent that is well within their power of recovery—or, as it is technically expressed, is within the elastic limit of the material—can be carried on indefinitely only so long as every particle of the material so stressed is harmoniously in accord with its neighbours. It might well be that a very mild stress for the majority of molecules might seriously disconcert a small group occupying some particular spot near the edge, or perhaps near the core of the object in question. To these particular molecules, which are in some

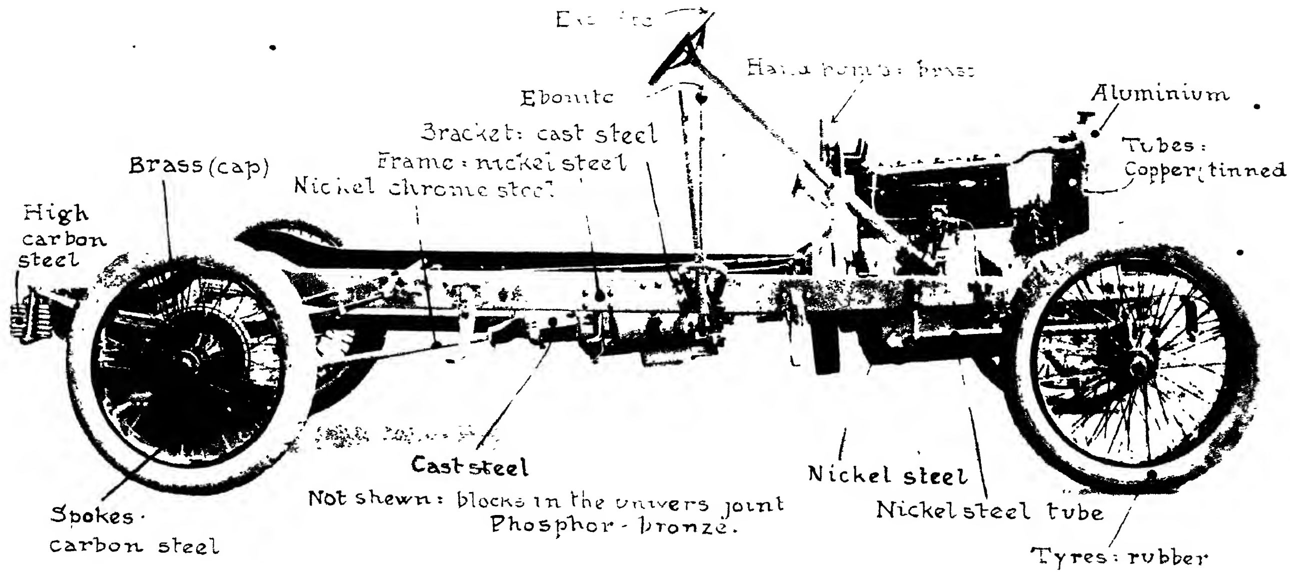
way abnormal, the stress is excessive, and, after many repetitions, they give way under the strain, and in doing so they spread their disaffection gradually through the rest of the material until it breaks down completely.

Inherent faults of this description are the more difficult to detect because they often show no signs of being present when the piece as a whole is tested for its strength against one direct pull. If, of course, the piece is put in a special testing machine and rotated out of line so that it is subject to an alternating stress for a long period of time, a more exact idea of the suitability of the material for the practical uses to which it is to be put in the motor-car will be available, but, unfortunately, the test is somewhat of a special character and the usual way of denoting the virtues of the standard steels of commerce is to refer to their tensile strength against one direct steady pull. As an isolated indication of merit the direct tensile test is useless, but taken in conjunction with a variety of other tests, it serves, of course, a very good purpose.

Alone, and without reference to other matters, it is apt to be very misleading, partly because it seldom shows any indication of the minute internal irregularities that are subsequently going to cause fatigue, and, also, because a material is sometimes made artificially to appear strong as the result of some particular process incidental to manufacture.

For example, a cold rolled bar of steel will often derive artificial strength from the hard skin that is the result of direct contact with the rollers, but as this intense local pressure has certainly caused internal disturbances of just the kind that are likely to develop into weaknesses with time and vibration, it would be fatal to rely upon the apparent strength of such a specimen in the condition that it is received.

And again, even supposing that one made allowances, one would still never be certain that they were proper to individual pieces. When one says that the effect of rolling, or of this or that other process that has been incidental to the manufacture of the part, has caused internal irregularities, one is not by any means specifying the magnitude of the trouble, and there is no reason whatever to suppose that it will necessarily be uniform in amount. Indeed, it may be said with some truth that the whole reason for studying the subject of metallurgy in engineering more scientifically than hitherto was customary, is due to the fact that experience has proved how utterly unreliable is any such assumpton. Simple rule-of-thumb methods would otherwise have enabled everyone to guard against failures, after a few preliminary mishaps, by merely making a part larger in order that it might be stronger. Internal weakness, however, baffles such unscientific remedies entirely, because the fault that lies unsus-



SOME OF THE MATERIALS IN A DAIMLER CHASSIS

Many different kinds of material are employed in the construction of a motor-car, and the above illustration indicates the nature of the more important parts.

pected inside is not necessarily to be prevented from developing by the mere magnitude of the specimen as a whole. The more there is of the material, in fact, the more there is, in a way, of the weakness.

Now all this sounds very alarming to the uninitiated, who may well ask how can one possibly detect or cure a fault that the eye cannot see, in a material that is apparently quite up to specification so far as its chemical composition is concerned. The fact that the naked eye cannot see the fault is true enough, but it is not true that the weakness is utterly invisible. If a piece of steel is broken and a minute spot of the fracture, say the size of a pin's head or less, is examined under the most powerful of microscopes so that the object looked at expands itself into a picture some two or three inches across, then the eye can indeed see a very great deal that formerly was hidden.

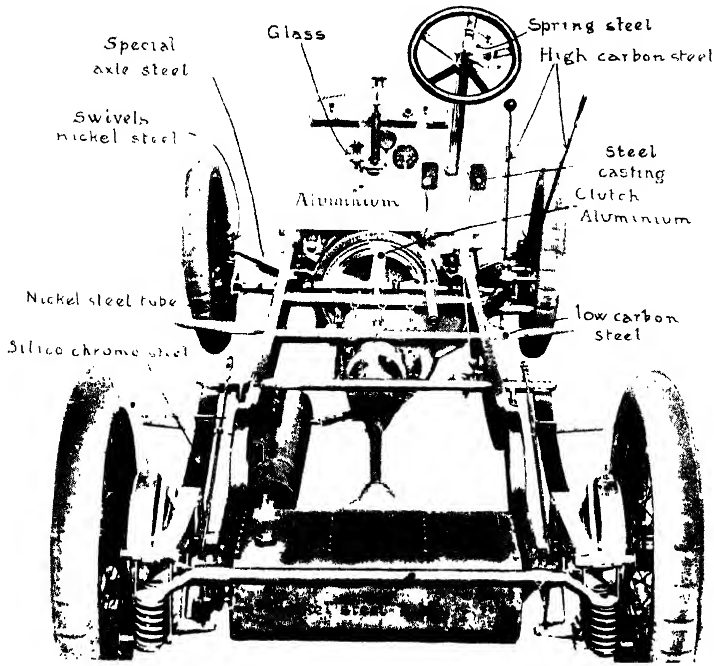
The very arrangement of the molecules is laid bare, and if the same piece of metal is thus examined after it has been subjected to a series of heat treatments, which have consisted in baking in a furnace and then cooling off either in the air, oil or some other suitable quenching medium, the changes that take place in its structure can readily be examined. If this examination is compared with the results obtained from the material under proper tests, there is slowly built up in the course of time a great tome of actual inform-

ation that forms the foundation of a practical science ; but, inasmuch as the appearance of metal under the microscope is only a writing on the wall to those who can read it in the light of experience, it is easy to believe how slowly and laboriously the information is collected. For the same reason, it can readily be understood how inestimably valuable, to the manufacturer and to those for whom he makes his cars, is the experience thus collected.

To the motorist, it is surely of the very greatest interest to learn something of this aspect of the building of his car, but it has, unfortunately, been exceedingly difficult for the general reader to find information of this character in a convenient and comprehensible form. It is *au fond* a technical subject, but then, so also are other branches of automobile engineering, yet they certainly prove of interest to the car owner, as witness the support that he extends to the technical motoring Press. In fine, the subject of metallurgy and particularly the aspect of metallurgy that is called metallography, having to do with the appearance of materials under the microscope, has seldom been " written up " for the motorist in a popular form, and I may therefore perhaps be pardoned for referring those who may be interested further to pursue the detail of this subject to a book called *Notes on the Materials of Motor-car Construction*, which I wrote, with the assistance of

CASE HARDENING

A good example of case hardening, showing the tough fibrous core of metal underlying the intensely hard but brittle shell. The illustration is of a gear-wheel that has been purposely fractured The specimen was prepared at the Daimler factory.



GENERAL VIEW OF A DAIMLER CHASSIS, SHOWING THE VARIOUS MATERIALS USED IN ITS CONSTRUCTION

Mr. W. H. Proctor, Mr. T. W. Picken, Mr. A. Harley, and others of the Daimler Company's metallurgical staff, for this purpose. In any case, space precludes more than this mere introduction to a very fascinating subject being given in the present volume.

APPENDIX

Length

1 in. = 25·4 cms.
1 ft. = 0·305 m.
1 yd. = 0·914 m.
1 mile = 5280 ft.
= 1760 yds.
= 1·61 km.
1 sea mile = 6080 ft.
1° Equator = 60 sea mi.
1 m. = 3·28 ft.

Area

1 ft.^{2} = 144 in.^{2}
= 0·093 m.^{2}
1 m.^{2} = 10·76 ft.^{2}
1 yd.^{2} = 0·836 m.^{2}
1 acre = 4840 yd.^{2}
= 4046·7 m.^{2}
1 sq. mile = 640 acres.

Weight

1 oz. = 28·35 grammes
1 lb. = 16 oz.
= 0·4536 kg.
= 445,000 dynes
1 ton = 2240 lbs.
= 1016·05 kg.
1 U.S.A. ton = 2000 lbs.
1 kg. = 2·2 lbs.
= 981,000 dynes

Couples

1 kg. m. = 7·25 lb. ft.
1 lb. ft. = 0·138 kg. m.

Pressure

1 kg./m.^{2} = 0·205 lbs./ft.^{2}
1 lb./ft.^{2} = 4·9 kg./m.^{2}
1 lb./in.^{2} = 0·07 kg./cm.^{2}
= 68,976 dynes/cm.^{2}
= 2·04″ Hg. @ 62° F.
= 2·3 ft. H_2O ,,
1″ H_2O @ 62° F. = 5·196 lbs./ft.^{2}
= 0·073″ Hg.
= 65 ft. air
1 atm. @ 62° F. = 29·95″ Hg.
= 760 mm. Hg.
= 33·94 ft. H_2O
= 14·76 lbs./in.^{2}
= 1×10^6 dynes/cm.^{2}
= ·95 ton/ft.^{2}
1 kg./cm.^{2} = 14·223 lbs./in.^{2}
= ·975 atmospheres
1 oz./yd.^{2} = 33·9 grammes/m.^{2}

Velocity

1 m.p.h. = 1·46 ft./sec.
= 88 ft./min.
= 1·609 k.p.h.
= ·445 m./sec.
1 knot = 1·152 m.p.h.
1 k.p.h. = 0·6214 m.p.h.
= 0·9113 ft./sec.
1 cm./sec. = 2 ft./min. (appx.)
1 ft./sec. = 0·685 m.p.h.
1 m./sec. = 2·25 m.p.h.

Sound in Air 1142 ft./sec.

Density (ρ)

If sp. gr. water = 1·00
then lb./in.^{3} = sp.gr. × ·036
1 gramme/cm^3 = 62·43 lbs./ft.^{3}
1 kg./m^3 = 0·0623 lbs./ft.^{3}
1 lb./ft.^{3} = 15·8 kgs./m.^{3}
Air = 0·08 lbs./ft.^{3}
= 1·29 kg./m.^{3}
Hydrogen = 0·005 lbs./ft.^{3}
= 0·0895 kg./m.^{3}
Coal gas = 0·0403 lbs./ft.^{3}
= 0·646 kg./m.^{3}
Water = 62·5 lbs./ft.^{3}
= 10 lbs./gal.
Petrol (·72 sp. gr.) = 45 lbs./ft.^{3}
= 7·2 lbs./gal.
Ash = 49 lbs./ft.^{3}
Bamboo = 25 ,,
Cork = 15 ,,
Mahogany = 40 ,,
Oak = 50 ,,
Pine = 36 ,,
Spruce = 31 ,,
Walnut = 42 ,,

Wind

Altitude. ft.	Velocity. m.p.h.
1,000	10
2,000	20
3,000	25
4,000	28
6,000	30
8,000	32
12,000	35

The Atmosphere

Altitude. ft.	Density ρ lbs./ft.^{3}
0	0·78
4,000	0·68
8,000	0·59
12,000	0·51
16,000	0·47
20,000	0·41

POWER

1 h.p. = 375 mile lbs./hour
= 33000 ft. lbs./min.
= 550 ft. lbs./sec.
= 77·5 kg. metres/sec.
= 0·746 kilowatts
= 42·416 B.Th.U./min. (lb. ° F.)
= 10·711 calories/min. (kg°. C.)
= 0·175 lbs. carbon oxidized/hour
= 2·64 lbs. water evaporated @ 212° F./hour

Joules equivalent : 1 B.Th.U. = 772 ft. lbs.

TEMPERATURE

°C. = 0·555 (°F. − 32)
°F. = 32 + (1·8° C.)

Absolute zero = − 459° F.
= − 273° C.

The earth, increase in temp. with depth + 1° C. per 100 ft. (approx.).

The atmosphere, decrease in temp. with altitude :—

4000 ft. . . . − 2½° F. per 1000 ft.
16000 ft. . . . − 3° F. ,, ,,
17000 ft. . . . − 3½° F. ,, ,,
28000 ft. . . . − 4° F. ,, ,,

VOLUME

1 gal. = 8 pts.
= 160 fl. ozs.
= 227·27 in.^{3}
= 0·16 ft.^{3}
= 4·546 Litres
1 U.S.A. gal. = 231 in.^{3}
1 litre = ·1 m.^{3}
= 1·76 pts.
= 61·02 in.^{3}
= 0·22 gallon
1 ft.^{3} = 1728 in.^{3}
= 50 pints
= ·0283 m.^{3}
1 m.^{3} = 35·315 ft.^{3}
= 1·307 yds.^{3}
1 fluid oz. = 480 drops H_2O
1 teaspoonful = 60 drops (abt.)

ANGULAR

1 circle = 360°
1 radian = 360° ÷ 2π
= 57·296°
ω = angular velocity
= radians/sec.
= 2π revs./sec.
Revs./sec. = $\omega/2\pi$

DIMENSIONS

Velocity LT^{-1}
Acceleration LT^{-2}
Kinematic viscosity L^2T^{-1}
Density ML^{-3}
Force MLT^{-2}

Temperature. °Fahr.		°Cent.
0	=	−18
10	=	−12
20	=	− 7
32	=	0
40	=	4
50	=	10
60	=	16
70	=	21
80	=	27
90	=	32
100	=	38
110	=	43
120	=	49
130	=	54
140	=	60
150	=	65
160	=	71
170	=	77
180	=	82
190	=	88
200	=	93
212	=	100
220	=	104
230	=	110
240	=	115
250	=	121
260	=	126
270	=	132

Weight. Cwts.		Kgs.
5	=	254
10	=	508
12	=	610
14	=	712
16	=	813
18	=	915
20	=	1,016
22	=	1,118
24	=	1,220
26	=	1,321
28	=	1,423
30	=	1,524
32	=	1,626
34	=	1,728
36	=	1,829
38	=	1,931
40	=	2,032
42	=	2,134
44	=	2,235
46	=	2,337
48	=	2,438
50	=	2,540
52	=	2,640
54	=	2,740
56	=	2,840
58	=	2,940
60	=	3,050

Miles per gal.		Litres per 100 kiloms.
5	=	55
6	=	48
7	=	40
8	=	36
9	=	31
10	=	28
11	=	26
12	=	23
13	=	22
14	=	20
15	=	19
16	=	18
17	=	17
18	=	16
19	=	15
20	=	14
21	=	13·5
22	=	13·0
23	=	12·0
24	=	11·5
25	=	11·2
26	=	10·8
27	=	10·4
28	=	10·0
29	=	9·6
30	=	9·4
31	=	9·1
32	=	8·8
33	=	8·5
34	=	8·3
35	=	8·0

Exchange. £	s.	d.		fr.	c.
0	0	1	=	0	10
0	0	2	=	0	20
0	0	3	=	0	30
0	0	4	=	0	40
0	0	5	=	0	50
0	0	6	=	0	60
0	0	7	=	0	70
0	0	8	=	0	80
0	0	9	=	0	90
0	0	10	=	1	0
0	0	11	=	1	10
0	1	0	=	1	20
0	2	0	=	2	50
0	3	0	=	3	70
0	4	0	=	5	0
0	5	0	=	6	30
0	6	0	=	7	50
0	7	0	=	8	80
0	8	0	=	10	0
0	9	0	=	11	30
0	10	0	=	12	50
1	0	0	=	25	0
2	0	0	=	50	0
3	0	0	=	75	0
4	0	0	=	100	0
5	0	0	=	126	0
10	0	0	=	252	0

The above tables are only approximate.

MENSURATION

Surfaces—

Triangle $=$ Base $\times \frac{1}{2}$ perpendicular.
Circle $= D^2 \times \cdot 7854$.
Sector $=$ Arc $\times \frac{1}{2}$ radius.
Parabola $=$ Base $\times \frac{2}{3}$ height.
Ellipse $=$ Major axis $\times \cdot 7854$ minor axis.
Cone $=$ Base area $+$ (Base circ. $\times \frac{1}{2}$ slant height).
Sphere $= D^2 \times 3 \cdot 14159$.

Volumes—

Cylinder $=$ Base area $\times$ length.
Sphere $= D^3 \times \cdot 5236$.
Segment $= \cdot 5236$ Height (Height$^2 + 3$ Base Radius).
Cone $=$ Base area $\times \frac{1}{3}$ perpendicular.
Wedge $=$ Base area $\times \frac{1}{2}$ perpendicular.

The Circle—

Circumference $= D \times 3 \cdot 14159$.
Equal Square $= D \times 0 \cdot 886226$.
Inscribed ,, $= D \times 0 \cdot 7071$.

Feet.		Metres.	Miles.		Kiloms.	Gallons.		Litres.	Lbs.		Kgs.
1	=	·3	1	=	1·6	1	=	4·5	1	=	·45
2	=	·6	2	=	3·2	2	=	9·0	2	=	·9
3	=	·9	3	=	4·8	3	=	13·6	3	=	1·4
4	=	1·2	4	=	6·4	4	=	18·2	4	=	1·8
5	=	1·5	5	=	8·0	5	=	22·7	5	=	2·3
6	=	1·8	6	=	9·6	6	=	27·3	6	=	2·7
7	=	2·1	7	=	11·2	7	=	31·8	7	=	3·2
8	=	2·4	8	=	12·8	8	=	36·3	8	=	3·6
9		2·7	9	=	14·5	9	=	40·9	9	=	4·1
10	=	3·0	10	=	16·1	10	=	45·4	10	=	4·5

Cu. ins.		Cu. cms.	Sq. ft.		Sq. metres.	Per lb. s.	d.		Per kilog. fr.	c.	Per yard. s.	d.		Per metre fr.	c.
1	=	16·3	1	=	·09	1	0	=	2	80	1	0	=	1	40
2	=	32·7	2	=	·18	2	0	=	5	60	2	0	=	2	80
3	=	49·1	3	=	·28	3	0	=	8	40	3	0	=	4	15
4	=	65·5	4	=	·37	4	0	=	11	10	4	0	=	5	50
5	=	81·9	5	=	·46	5	0	=	13	90	5	0	=	6	90
6	=	98·3	6	=	·56	6	0	=	16	70	6	0	=	8	30
7	=	114·7	7	=	·65	7	0	=	19	50	7	0	=	9	65
8	=	131·1	8	=	·74	8	0	=	22	30	8	0	=	11	10
9	=	147·5	9	=	·84	9	0		25	0	9	0	=	12	40
10	=	163·0	10	=	·92	10	0	=	27	80	10	0	=	13	80

Pressure. Lbs. per sq. in.		Atmospheres (or kilogs. per sq. centimetre).		Metres d'eau.	*Price of Petrol.* Per gal. s.	d.		Per litre. c.		Per bidon. fr.	c.
1	=	·07	=	0·7	1	0	=	28	=	1	40
2	=	·14	=	1·4	1	1	=	30	=	1	50
3	=	·2	=	2·1	1	2	=	33	=	1	65
4	=	·27	=	2·8	1	3	=	35	=	1	75
5	=	·34	=	3·5	1	4	=	37	=	1	85
6	=	·41	=	4·2	1	5	=	39	=	1	95
7	=	·48	=	4·9	1	6	=	42	=	2	10
8	=	·54	=	5·6	1	7	=	44	=	2	20
9	=	·61	=	6·3	1	8	=	46	=	2	30
10	=	·68	=	7·0	1	9	=	49	=	2	45
20	=	1·4	=	14·0	1	10	=	51	=	2	55
30	=	2·0	=	21·0	1	11	=	53	=	2	65
40	=	2·7	=	28·0	2	0	=	55	=	2	75
50	=	3·4	=	35·0	2	1	=	58	=	2	90
60	=	4·1	=	42·0	2	2	=	60	=	3	0
70	=	4·7	=	49·0	2	3	=	63	=	3	15
80	=	5·4	=	56·0	2	4	=	65	=	3	25
90	=	6·1	=	63·0	2	5	=	67	=	3	35
100	=	6·8	=	70·0	2	6	=	69	=	3	45

The above tables are only approximate.

Compass

Points.		Angle. °	′	″
¼	=	2	48	45
½	=	5	37	30
¾	=	8	26	15
1	=	11	15	0
1¼	=	14	3	45
1½	=	16	52	30
1¾	=	19	41	15
2	=	22	30	0
2¼	=	25	18	45
2½	=	28	7	30
2¾	=	30	56	15
3	=	33	45	0
3¼	=	36	33	45
3½	=	39	22	30
3¾	=	42	11	15
4	=	45	0	0

Miles per hour.		Kiloms. per hour.
Only approximate.		
5	=	8
10	=	16
15	=	24
20	=	32
22	=	35
24	=	38
26	=	41
28	=	45
30	=	48
32	=	51
34	=	54
36	=	57
38	=	61
40	=	64
42	=	67
44	=	71
46	=	74
48	=	77
50	=	80
52	=	83
54	=	86
56	=	90
58	=	93
60	=	100
64	=	103
66	=	106
68	=	110
70	=	113
72	=	116
74	=	119
76	=	122
78	=	125
80	=	128
90	=	144
100	=	160
105	=	168
110	=	176
120	=	193

Morse Code

A	• ▬
B	▬ • • •
C	▬ • ▬ •
D	▬ • •
E	•
F	• • ▬ •
G	▬ ▬ •
H	• • • •
I	• •
J	• ▬ ▬ ▬
K	▬ • ▬
L	• ▬ • •
M	▬ ▬
N	▬ •
O	▬ ▬ ▬
P	• ▬ ▬ •
Q	▬ ▬ • ▬
R	• ▬ •
S	• • •
T	▬
U	• • ▬
V	• • • ▬
W	• ▬ ▬
X	▬ • • ▬
Y	▬ • ▬ ▬
Z	▬ ▬ • •

Numerals

1	• ▬ ▬ ▬ ▬
2	• • ▬ ▬ ▬
3	• • • ▬ ▬
4	• • • • ▬
5	• • • • •
6	▬ • • • •
7	▬ ▬ • • •
8	▬ ▬ ▬ • •
9	▬ ▬ ▬ ▬ •
0	▬ ▬ ▬ ▬ ▬

Formulæ of the Hydrocarbons, etc., of Importance in Connection with Liquid Fuel

1. The paraffin series—C_nH_{2n+2}

Methane	CH_4		gas	
Ethane	C_2H_6		gas	
Propane	C_3H_8		gas	
Butane	C_4H_{10}		gas	
Pentane	C_5H_{12}	boils at 37° C.		Spirit, the benzines or naphthas.
Hexane	C_6H_{14}	,, 69	petrol	
Neptane	C_7H_{16}	,, 98	petrol	
Octane	C_8H_{18}	,, 120	petrol	
Nonane	C_9H_{20}	,, 130		
Decane	$C_{10}H_{22}$	,, 158	Kerosene or lamp oil, "Solar" or Intermediate oil,	
Undecane	$C_{11}H_{24}$	,, 180		
Duodecane	$C_{12}H_{26}$	,, 200		
etc. etc.			Lubricating oil, Vaseline, Wax.	
	$C_{17}H_{36}$			
etc. etc.				

2. The Olefine series C_nH_{2n}
   Ethylene C_2H_4
   etc. etc.

3. The Acetylene series C_nH_{2n-2}
   Acetylene C_2H_2
   etc. etc.

4. The Benzene series C_nH_{2n-6}
   Benzene C_6H_6 boils at 81° C. } Benzol.
   Toluene C_7H_8 ,, 111° C. } Benzol.
   Xylene C_8H_{10}
   etc.

5. Naphthalene C_nH_{2n-12}
   Naphthalene $C_{10}H_8$ boils at 218° C.

6. Alcohol C_2H_5OH
   Methylic Alcohol CH_4O boils at 63° C.
   Ethylic ,, C_2H_6O ,, 78° C.

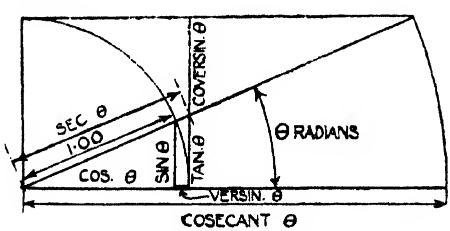


Diagram illustrating the trigonometrical ratios.

ALTITUDE (METRES) Corresponding to Barometer mm.

Bar. mm.	Mean Temperature, ° C.				
	20°.	10°.	0°.	-10°.	-20°.
770	-90	-87	-84	-81	-78
760	33	22	21	20	19
750	137	132	127	123	118
740	252	243	235	227	219
730	369	356	344	332	320
720	488	471	455	439	423
710	608	587	567	547	527
700	730	705	680	656	632
690	854	825	796	767	738
680	980	946	913	880	847
670	1,107	1,070	1,032	994	956
660	1,237	1,195	1,152	1,109	1,067
650	1,368	1,322	1,275	1,228	1,181
640	1,502	1,450	1,399	1,348	1,297
630	1,637	1,581	1,525	1,469	1,413
620	1,775	1,714	1,654	1,593	1,532
610	1,915	1,850	1,784	1,718	1,653
600	2,057	1,987	1,917	1,847	1,777
590	2,202	2,127	2,052	1,977	1,902
580	2,349	2,269	2,189	2,109	2,029
570	2,499	2,414	2,328	2,243	2,158
560	2,651	2,561	2,470	2,380	2,290
550	2,807	2,711	2,615	2,519	2,423
540	2,965	2,863	2,762	2,661	2,560
530	3,126	3,019	2,912	2,805	2,698
520	3,290	3,177	3,065	2,953	2,841
510	3,457	3,339	3,221	3,103	2,985
500	3,628	3,504	3,380	3,256	3,132
490	—	3,672	3,542	3,412	3,282
480	—	3,843	3,708	3,572	3,436
470	—	4,019	3,876	3,734	3,592
460	—	4,198	4,049	3,901	3,753
450	—	4,380	4,226	4,071	3,916
440	—	4,567	4,406	4,245	4,083
430	—	4,759	4,591	4,422	4,253
420	—	4,955	4,780	4,604	4,428
410	—	5,155	4,973	4,791	4,608
400	—	5,361	5,171	4,982	4,792
390	—	5,572	5,375	5,178	4,981
380	—	5,788	5,583	5,379	5,174
370	—	6,010	5,797	5,585	5,372
360	—	6,238	6,017	5,797	5,576
350	—	6,473	6,244	6,015	5,786
340	—	6,714	6,477	6,239	6,002
330	—	6,963	6,716	6,470	6,224
320	—	7,219	6,964	6,709	6,453
310	—	7,483	7,219	6,954	6,690
300	—	7,757	7,482	7,208	6,934
290	—	8,039	7,755	7,471	7,186
280	—	8,331	8,037	7,742	7,448
270	—	8,634	8,329	8,024	7,718
260	—	8,949	8,633	8,317	8,000
250	—	9,276	8,948	8,620	8,292
200	—	11,153	10,742	10,348	9,954
150	—	13,536	13,058	12,579	12,101
100	—	16,925	16,327	15,729	15,130
50	—	22,717	21,914	21,110	20,308

SINES AND TANGENTS

Degs.	Sine.	Tangent		Degs.	Sine.	Tangent.	
0	·00000	·00000	90	46	·71934	1·03553	44
1	·01745	01746	89	47	·73135	1·07237	43
2	·03490	03492	88	48	·74314	1·11061	42
3	·05234	·05241	87	49	·75471	1·15037	41
4	·06976	·06993	86	50	·76604	1·19175	40
5	·08716	·08749	85	51	·77715	1·23490	39
6	·10453	·10510	84	52	·78801	1·27994	38
7	·12187	·12278	83	53	·79864	1·32704	37
8	·13917	·14054	82	54	·80902	1·37638	36
9	·15643	·15838	81	55	·81915	1·42815	35
10	·17365	·17633	80	56	·82904	1·48256	34
11	·19081	·19438	79	57	·83867	1·53987	33
12	·20791	·21256	78	58	·84805	1·60033	32
13	·22495	·23087	77	59	·85717	1·66428	31
14	·24192	·24933	76	60	·86603	1·73205	30
15	·25882	·26795	75	61	·87462	1·80405	29
16	·27564	·28675	74	62	·88295	1·88073	28
17	·29237	·30573	73	63	·89101	1·96261	27
18	·30902	·32492	72	64	·89879	2·05030	26
19	·32557	·34433	71	65	·90631	2·14451	25
20	·34202	·36397	70	66	·91355	2·24604	24
21	·35837	·38386	69	67	·92050	2·35585	23
22	·37461	·43403	68	68	·92718	2·47509	22
23	·36073	·42447	67	69	·93358	2·60509	21
24	·40674	·44523	66	70	·93969	2·74748	20
25	·42262	·44631	65	71	·94552	2·90421	19
26	·43837	·48773	64	72	·95106	3·07768	18
27	·45399	·50593	63	73	·95630	3·27085	17
28	·46947	·53171	62	74	·96126	3·48741	16
29	·48481	·55431	61	75	·96593	3·73205	15
30	·50000	·57735	60	76	·97030	4·01078	14
31	·51504	·60086	59	77	·97437	4·33148	13
32	·52992	·62487	58	78	·97815	4·70463	12
33	·54464	·64941	57	79	·98163	5·14455	11
34	·55919	·67451	56	80	·98481	5·67128	10
35	·57358	·70021	55	81	·98769	6·31375	9
36	·58779	·72654	54	82	·99027	7·11537	8
37	·60182	·75355	53	83	·99255	8·14435	7
38	·61566	·78129	52	84	·99452	9·51436	6
39	·62329	·80978	51	85	·99619	11·43005	5
40	·64279	·83910	50	86	·99756	14·30067	4
41	·65606	·86929	49	87	·99863	19·08114	3
42	·66913	·90040	48	88	·99939	28·63625	2
43	·68200	·93252	47	89	·99985	57·28996	1
44	·69466	96569	46	90	1·00000	Infinite	0
45	·70711	1·00000	45				
	Cosine.	Contangent.	Degs.		Cosine.	Contangent.	Degs.

COSINES AND CONTANGENTS

LOGARITHMS

No.	0	1	2	3	4	5	6	7	8	9
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374
11	0414	0453	0492	0531	0569	0707	0645	0682	0719	0755
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279
17	2304	2330	1355	2380	2405	2430	2455	2480	2504	2529
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989
20	3010	3032	2054	3075	3096	3118	3139	3160	3181	3201
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551
36	5513	5575	5557	5599	5611	5623	5635	5647	5658	5670
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425
44	6435	6444	6454	6464	6474	6484	6494	6503	6513	6522
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803
48	6812	6821	6830	6839	6846	6857	6866	6875	6884	6893
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	8681
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396

LOGARITHMS—*continued*

No.	0	1	2	3	4	5	6	7	8	9
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186
83	9191	9196	9201	9206	9217	9212	9222	9227	9232	9238
84	9243	9248	9253	9258	9262	9263	9274	9279	9284	9289
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633
92	9638	9643	9647	9652	9657	9661	9666	9671	9175	9680
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996

PERMANENT LIGHTING-UP TIMES (on the safe side of the law).

Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
5.0	5.40	6.40	7.30	8.20	9.0	9.15	8.40	7.40	6.30	5.30	4.50
5.10	6.0	6.50	7.40	8.30	9.10	9.10	8.30	7.10	6.10	5.10	4.50
5.20	6.20	7.10	8.0	8.40	9.15	9.0	8.10	6.50	5.50	5.0	4.50
5.30	6.30	7.20	8.10	8.50	9.15	8.50	7.50	6.40	5.40	4.50	4.50

The top line of figures relates to the first week of the month, etc.

Kg.	= lb.	Kg.	= lb.	Kg.	= Cwt.	lb.	Kg.	= Cwt.	lb.
1	2·20	20	44·09	100	1	108·5	2000	39	41·2
2	4·41	30	66·14	200	3	104·9	3000	59	5·9
3	6·61	40	88·18	300	5	101·4	4000	78	82·5
4	8·82	50	110·23	400	7	97·8	5000	98	47·1
5	11·02	60	132·28	500	9	94·3	6000	118	11·7
6	13·23	70	154·32	600	11	90·8	7000	137	88·4
7	15·43	80	176·37	700	13	87·2	8000	157	53·0
8	17·64	90	198·42	800	15	83·7	9000	177	17·6
9	19·84	100	220·46	900	17	80·2	10,000	196	94·2
10	22·05			1000	19	76·6			

PRICE EQUIVALENTS (Francs)

Shillings to Francs.		Francs to Shillings.		Shgs. per ft. to Frs. per m.		Frs. per m to Shgs. per ft.	
s.	fr.	fr.	s.	s.	fr.	fr.	s.
100 =	126·10	100 =	79·29	10 =	41·37	10 =	2·42
200 =	252·20	200 =	158·58	20 =	82·74	20 =	4·83
300 =	378·30	300 =	237·87	30 =	124·11	30 =	7·25
400 =	504·40	400 =	317·16	40 =	165·49	40 =	9·67
500 =	630·50	500 =	396·46	50 =	206·86	50 =	12·09
600 =	756·60	600 =	475·75	60 =	248·22	60 =	14·50
700 =	882·70	700 =	555·04	70 =	289·60	70 =	16·92
800 =	1008·80	800 =	634·33	80 =	330·97	80 =	19·34
900 =	1134·90	900 =	713·62	90 =	372·34	90 =	21·75
1000 =	1261·00	1000 =	792·91	100 =	413·71	100 =	24·17

Shgs. per yd. to Frs. per m.		Frs. per m. to Shgs. per yd.		Shs. per sq. ft. to Frs. per sq. m.		Frs. per sq. m. to S. per sq. ft.	
s.	fr.	fr.	s.	s.	fr.	fr.	s.
10 =	13·79	10 =	7·25	10 =	135·73	10 =	0·74
20 =	27·58	20 =	14·50	20 =	271·47	20 =	1·47
30 =	41·37	30 =	21·75	30 =	407·20	30 =	2·21
40 =	55·16	40 =	29·01	40 =	542·93	40 =	2·95
50 =	68·95	50 =	36·26	50 =	678·66	50 =	3·68
60 =	82·74	60 =	43·51	60 =	814·40	60 =	4·42
70 =	96·53	70 =	50·76	70 =	950·13	70 =	5·16
80 =	110·32	80 =	58·01	80 =	1085·86	80 =	5·89
90 =	124·11	90 =	65·26	90 =	1221·60	90 =	6·63
100 =	137·90	100 =	72·51	100 =	1357·33	100 =	7·37

PRICE EQUIVALENTS (Francs)

Continued

Shgs. per sq. yd. to Frs. per sq. m.	
s.	*fr.*
10 =	15·08
20 =	30·16
30 =	45·24
40 =	60·33
50 =	75·41
60 =	90·49
70 =	105·57
80 =	120·65
90 =	135·73
100 =	150·82

Frs. per sq. m. to Shgs. per sq. yd.	
fr.	*s.*
10 =	6·63
20 =	13·26
30 =	19·89
40 =	26·52
50 =	33·15
60 =	39·78
70 =	46·42
80 =	53·04
90 =	59·68
100 =	66·31

Shgs. per c. ft. to Frs. per cub. metre.	
s.	*fr.*
10 =	445·32
20 =	890·64
30 =	1335·96
40 =	1781·28
50 =	2226·60
60 =	2671·92
70 =	3117·24
80 =	3562·56
90 =	4007·88
100 =	4453·20

Frs. per c. m. to Shgs. per cub. ft.	
fr.	*s.*
100 =	2·25
200 =	4·49
300 =	6·74
400 =	8·98
500 =	11·23
600 =	13·47
700 =	15·72
800 =	17·96
900 =	20·21
1000 =	22·46

Shgs. per Gall. to Frs. per Hectolitre.	
s.	*fr.*
1 =	27·74
2 =	55·48
3 =	83·22
4 =	110·96
5 =	138·69
6 =	166·43
7 =	194·17
8 =	221·91
9 =	249·65
10 =	277·39

Frs. per Hectolitre to Shgs. per Gall.	
fr.	*s.*
100 =	3·61
200 =	7·21
300 =	10·82
400 =	14·42
500 =	18·03
600 =	21·63
700 =	25·24
800 =	28·84
900 =	32·45
1000 =	36·05

Shgs. per lb. to Frs. per Kilog.	
s.	*fr.*
10 =	27·80
20 =	55·60
30 =	83·40
40 =	111·20
50 =	139·00
60 =	166·80
70 =	194·60
80 =	222·40
90 =	250·20
100 =	278·00

Frs. per Kilog. to Shgs. per lb.	
fr.	*s.*
10 =	3·60
20 =	7·19
30 =	10·79
40 =	14·39
50 =	17·99
60 =	21·58
70 =	25·18
80 =	28·78
90 =	32·37
100 =	35·97

Shgs. per cwt. to Frs. per 100 Kilog.	
s.	*fr.*
10 =	24·82
20 =	49·64
30 =	74·46
40 =	99·29
50 =	124·11
60 =	148·93
70 =	173·65
80 =	198·57
90 =	223·39
100 =	248·22

Frs. per 100 Kilog. to Shgs. per cwt.	
fr.	*s.*
10 =	4·03
20 =	8·06
30 =	12·09
40 =	16·11
50 =	20·14
60 =	24·17
70 =	28·20
80 =	32·23
90 =	36·26
100 =	40·29

Shgs per 40 cub. ft. to Frs. per cub. m.	
s.	*fr.*
10 =	11·13
20 =	22·27
30 =	33·40
40 =	44·53
50 =	55·66
60 =	66·80
70 =	77·93
80 =	89·06
90 =	100·20
100 =	111·33

Frs. per cub. m. to Shgs per 40 cub. ft.	
fr.	*s.*
10 =	8·98
20 =	17·96
30 =	26·95
40 =	35·93
50 =	44·91
60 =	53·89
70 =	62·88
80 =	71·86
90 =	80·84
100 =	89·82

PRICE EQUIVALENTS (Marks)

Shillings to Marks.		Marks to Shillings.		Shgs. per ft. to Marks per m.		Mks. per m. to Shgs. per ft.	
s.	*m. pf.*	*m.*	*s.*	*s.*	*m. pf.*	*m.*	*s.*
100 =	102·00	100 =	98·04	10 =	33·46	10 =	2·99
200 =	204·00	200 =	196·08	20 =	66·93	20 =	5·98
300 =	306·00	300 =	294·12	30 =	100·39	30 =	8·97
400 =	408·00	400 =	392·16	40 =	133·86	40 =	11·95
500 =	510·00	500 =	490·20	50 =	167·32	50 =	14·94
600 =	612·00	600 =	588·24	60 =	200·79	60 =	17·93
700 =	714·00	700 =	686·28	70 =	234·23	70 =	20·92
800 =	816·00	800 =	784·31	80 =	267·72	80 =	23·91
900 =	918·00	900 =	882·35	90 =	301·18	90 =	26·89
1000 =	1020·00	1000 =	980·39	100 =	334·65	100 =	29·88

Shgs. per yd. to Marks per m.		Mks. per m. to Shgs. per yd.		Shgs. per sq. ft. to Mks. per sq. m.		Mks. per sq. m. to S. per sq. ft.	
s.	*m. pf.*	*m.*	*s.*	*s.*	*m. pf.*	*m.*	*s.*
10 =	11·15	10 =	8·96	10 =	109·79	10 =	0·91
20 =	22·31	20 =	17·93	20 =	219·58	20 =	1·82
30 =	33·46	30 =	26·89	30 =	329·38	30 =	2·73
40 =	44·62	40 =	35·86	40 =	439·17	40 =	3·64
50 =	55·77	50 =	44·82	50 =	548·96	50 =	4·55
60 =	66·93	60 =	53·79	60 =	658·75	60 =	5·46
70 =	78·08	70 =	62·75	70 =	768·54	70 =	6·38
80 =	89·24	80 =	71·72	80 =	878·33	80 =	7·29
90 =	100·39	90 =	80·68	90 =	988·13	90 =	8·20
100 =	111·55	100 =	89·65	100 =	1097·92	100 =	9·11

gs. per sq yd. to Marks per sq. m.		Mks. per sq. m. to Shgs. per sq. yd.		Shgs. per c. ft. to Mrks. per cub. metre.		Mks. per c. m. to Shgs per cub. ft.	
s.	*m. pf.*	*m.*	*s.*	*s.*	*m. pf.*	*m.*	*s.*
10 =	12·20	10 =	8·20	10 =	360·21	100 =	2·78
20 =	24·40	20 =	16·40	20 =	720·42	200 =	5·55
30 =	36·60	30 =	24·59	30 =	1080·63	300 =	8·33
40 =	48·80	40 =	32·79	40 =	1440·84	400 =	11·10
50 =	61·00	50 =	40·99	50 =	1801·06	500 =	13·88
60 =	73·20	60 =	49·18	60 =	2161·27	600 =	16·66
70 =	85·39	70 =	57·38	70 =	2521·48	700 =	19·43
80 =	97·59	80 =	65·58	80 =	2881·69	800 =	22·21
90 =	109·79	90 =	73·78	90 =	3241·90	900 =	24·99
100 =	121·99	100 =	81·97	100 =	3602·11	1000 =	27·76

PRICE EQUIVALENTS (Marks)

Continued

Shgs. per Gal. to Mks. per Hectolitre.		Mks. per Hectolitre to Shgs. per Gallon.		Shgs. per lb. to Marks per Kilogram.		Marks per Kilog. to Shillings per lb.	
s.	*m. pf.*	*m.*	*s.*	*s.*	*m. pf.*	*m.*	*s.*
1 =	22·44	100 =	4·46	10 =	22·49	10 =	4·45
2 =	44·87	200 =	8·91	20 =	44·97	20 =	8·89
3 =	67·31	300 =	13·37	30 =	67·46	30 =	13·34
4 =	89·75	400 =	17·83	40 =	89·95	40 =	17·79
5 =	112·19	500 =	22·28	50 =	112·44	50 =	22·23
6 =	134·62	600 =	26·74	60 =	134·92	60 =	26·68
7 =	157·06	700 =	31·20	70 =	157·41	70 =	31·13
8 =	179·50	800 =	35·65	80 =	179·90	80 =	35·58
9 =	201·94	900 =	40·11	90 =	202·38	90 =	40·02
10 =	224·37	1000 =	44 57	100 =	224·87	100 =	44·47

Shgs. per cwt. to Mrks. per 100 Kilog.		Mks. per 100 Kilog. to Shillings per cwt.		Shillings per 40 cub. ft. to Mrks. per cub. m		Mrks. per cub. m. to Shgs. per 40 cub. ft.	
s.	*m. pf.*	*m.*	*s.*	*s.*	*m. pf.*	*m.*	*s.*
10 =	20·08	10 =	4·98	10 =	9·01	10 =	11·10
20 =	40·16	20 =	9·96	20 =	18·01	20 =	22·21
30 =	60·23	30 =	14·94	30 =	27·02	30 =	33·31
40 =	80·31	40 =	19·92	40 =	36·02	40 =	44·42
50 =	100·39	50 =	24·90	50 =	45·03	50 =	55·52
60 =	120·47	60 =	29·88	60 =	54·03	60 =	66·63
70 =	140·54	70 =	34·86	70 =	63·04	70 =	77·73
80 =	160·62	80 =	39·84	80 =	72·04	80 =	88·84
90 =	180·70	90 =	44·83	90 =	81·05	90 =	99·94
100 =	200·78	100 =	49·81	100 =	90·05	100 =	111·05

MOTOR-CAR LAWS

Prior to 1861, motor-cars were simply carriages.

1861.—Locomotive Act limited weight to 12 tons, width to 7 ft., speed to 10 m.p.h. and fixed tolls.

1865.—Amendment: introduced Red Flag at 60 yards and gave local authorities power to limit hours of use in their areas. On Expiring Laws Continuance Act.

1873.—Select Committee's Report.

1878.—Amendment: abolished Red Flag but retained a man at 20 yards.

1896.—Locomotives on Highways Act: emancipated motor-cars under 3 tons from 1861 Act.

Speed limit 14 m.p.h. Additional excise. Local Government Board Powers.

Select Committee appointed on Locomotive Act.

1898.—Locomotive Act. Limited trailers to 3 plus 1 water cart, revoked local authorities' powers.

1903.—Motor-car Act. Speed limit 20 m.p.h. Registration. Licensing. Now on Expiring Laws Continuance Act.

1904.—Local Government Board Heavy Motor-car Order classified motor-cars, up to 2 tons and above.

Summary.

There are now four classes of motor-cars:—

Class I.—Heavy locomotives (exceeding 14 tons or 9 ft. in width by special permission only).

Class 2.—Ordinary locomotives (not exceeding 14 tons or 9 ft. in width).

Class 3.—Heavy motor-cars (from 2 to 5 tons).

Class 4.—Ordinary motor-cars (not exceeding 2 tons).

Restrictions on the Classes.

Classes 1 and 2.—Speed, country, 4 m.p.h.; towns, 2 m.p.h. Tyres, 2 in. width per ton except diameter exceed 5 ft.

Attendants, 2 drivers, 1 assistant per three trailers.

Class 3.—Loads, unladen, 5 tons, plus trailer, 6½ tons; loaded, 12 tons; axle weight, 8 tons; axle weight trailer, 4 tons. Width, 7 ft. 2 in. under 3 tons; 7 ft. 6 in. above 3 tons. Wheels minimum diameter, 2 ft. except rubber tyres. Iron tyres, ½ in. per ton axle weight, minimum 5 in.

Speed.—

5 m.p.h. if above 7 tons or 6 tons axle weight or has a trailer.
8 m.p.h. if above 6 tons axle weight with rubber tyres.
12 m.p.h. if less than 6 tons axle weight with rubber tyres.

Toll.—1 car = 1 horse. Trailers, 1 wheel = 1 horse.

Class 4.—Width 7 ft. 2 in. Speed 20 m.p.h. Reverse gear if above 5 cwt.

Motor Cycles.

No legal definition, but accepted as a motor-car with three wheels and under 3 cwt. Is also considered as a carriage.

Motor cycles must show a red tail light.

Yearly Excise Duty on Ordinary Motor-cars. (Pay at Post Office.)

Less than 4 wheels, 15*s*. Not exceeding 1 ton, £2 2*s*. Not exceeding 2 tons, £4 4*s*. Exceeding 2 tons, £5 5*s*. Chauffeur (as a manservant), 15*s*. Coat of Arms (except Club Badge), £2 2*s*.

1909 Budget—	£	*s*.	*d*.		£	*s*.	*d*.
Under 6½ h.p.	2	2	0	Under 33 h.p.	8	8	0
,, 12 h.p.	3	3	0	,, 40 h.p.	10	10	0
,, 16 h.p.	4	4	0	,, 60 h.p.	21	0	0
,, 26 h.p.	6	6	0	Over 60 h.p.	42	0	0

Rating of power is by R.A.C. formula: bore × bore × cylinders ÷ 2·5, e.g. a 4 cyl. engine of 4-inch bore is rated at 4 × 4 × 4 ÷ 2·5 = 25·6 h.p. and pays the four-guinea tax.

Taxes. (Pay Local Authority.)

Driver's licence, 5*s*. per annum. Registration fee, car, £1; cycle, 5*s*.: once only. Change of ownership, registration fee, car, 5*s*.; cycle, 1*s*.

MOTOR-CARS ABROAD

Speed Limits.

France.—30 k.p.h., country; 20 k.p.h., vicinity of buildings.
Austria-Hungary.—45 k.p.h., country; 15 k.p.h., towns.
Belgium.—30 k.p h., country; 10 k.p.h., towns.
Denmark.—30 k.p.h., country; 15 k.p.h., Copenhagen.
Germany.—15 k.p.h. at night.
Holland.—19 k.p.h., country; 13 k.p.h., towns.
Italy.—40 k.p.h., country; 12 k.p.h., towns.
Switzerland.—30 k.p.h., country; 9½ k.p.h., towns.

Rule of the Road.

As in England.—Austria-Hungary (except Carniola and Dalmatia), Portugal, Spain.
Elsewhere.—Keep to the right, pass on the left.

PETROL STORAGE REGULATIONS

[Clauses Nos. 4 to 7. These clauses do not apply if a licence for the storehouse is obtained from the Local Authority. A licence is essential if petrol is stored for sale.]

4. Where a storehouse forms part of, or is attached to another building, and where the intervening floor or partition is of an unsubstantial or highly inflammable character, or has an opening therein, the whole of such building shall be deemed to be the storehouse, and no portion of such storehouse shall be used as a dwelling or as a place where persons assemble. A storehouse shall have a separate entrance from the open air distinct from that of any dwelling or building in which persons assemble.

5. The amount of petroleum spirit to be kept in any one storehouse whether or not upon light locomotives, shall not exceed 60 gallons at any one time.

6. Where two or more storehouses are in the same occupation and are situated within 20 ft. of one another, they shall for the purposes of these Regulations be deemed to be one and the same storehouse, and the maximum amount of petroleum spirit prescribed in the foregoing Regulation shall be the maximum to be kept in all such storehouses taken together. Where two or more storehouses in the same occupation are distant more than 20 ft. from one another, the maximum amount shall apply to each storehouse.

7. Any person who keeps petroleum spirit in a storehouse which is situated within 20 ft. of any other building, whether or not in his occupation, or of any timber stack or other inflammable goods not owned by him, shall give notice to the Local Authority under the Petroleum Acts for the district in which he is keeping such petroleum spirit, that he is so keeping petroleum spirit, and shall renew such notice in the month of January in each year during the continuance of such keeping, and shall permit any duly authorized officer of the Local Authority to inspect such petroleum spirit at any reasonable time. This Regulation shall not apply to petroleum spirit kept in a tank forming part of a light locomotive.

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CARS BY GOODS TRAIN

(*Compiled by the Touring Department of the Royal Automobile Club.*)

Complete motor-cars, uncharged, are conveyed by goods train. Each one is charged by weight, station to station. The following table shows the mileage and charges for each car from 5 to 500 miles, at company's risk :—

For any distance not exceeding	Rate per ton, actual weight, Minimum 1 ton.		For any distance not exceeding	Rate per ton, actual weight. Minimum 1 ton.		For any distance not exceeding	Rate per ton, actual weight. Minimum 1 ton.		For any distance not exceeding	Rate per ton, actual weight. Minimum 1 ton.	
Miles.	s.	d.	Miles.	s.	d.	Miles.	s.	d.	Miles.	s.	d.
5	5	1	145	53	6	265	85	6	385	117	6
10	7	7	150	54	10	270	86	10	390	118	10
15	10	1	155	56	2	275	88	2	395	120	2
20	12	7	160	57	6	280	89	6	400	121	6
25	15	1	165	58	10	285	90	10	405	122	10
30	17	7	170	60	2	290	92	2	410	124	2
35	20	1	175	61	6	295	93	6	415	125	6
40	22	7	180	62	10	300	94	10	420	126	10
45	25	1	185	64	2	305	96	2	325	128	2
50	27	7	190	65	6	310	97	6	430	129	6
55	29	2	195	66	10	315	98	10	435	130	10
60	30	6	200	68	2	320	100	2	440	132	2
65	31	11	205	69	6	325	101	6	445	133	6
70	33	3	210	70	10	330	102	10	450	134	10
75	34	8	215	72	2	335	104	2	455	136	2
80	36	0	220	73	6	340	105	6	460	137	6
85	37	5	225	74	10	345	106	10	465	138	10
90	38	9	230	76	2	350	108	2	470	140	2
95	40	2	235	77	6	355	109	6	475	141	6
100	41	6	240	78	10	360	110	10	480	142	10
105	42	10	245	80	2	365	112	2	485	144	2
110	44	2	250	81	6	370	113	6	490	145	6
115	45	6	255	82	10	375	114	10	495	146	10
120	46	10	260	84	2	380	116	2	500	148	2
125	48	2									
130	49	6									
135	50	10									
140	52	2									

In the case of traffic to London the above mileage rates are applicable only to the stations of the railway company carrying the traffic into London, and not beyond to any other London station.

FOREIGN TOURING

Information compiled by the Touring Department of the Royal Automobile Club for the use of members, and reproduced by permission.

This table is approximate only. In order to make it as plain as possible, decimals have been avoided.

CONTINENTAL CUSTOMS DUTIES

DEPOSITS BASED ON WEIGHT

Weight.		France.		Germany.	Switzerland.		Italy.	Austria.
cwts.	kgs.	£ s. d.	frs.	£ s. d.	£ s. d.	frs.	£ s. d.	£ s. d.
5	254	10 3 4	254	5 0 0	4 1 8	102	8 0 0	15 5 0
10	508	15 5 0	381	6 5 0	8 3 4	203	16 17 0	24 10 0
11	559	16 15 6	420	6 17 6	8 19 8	224	16 17 0	26 19 0
12	610	18 6 0	453	7 10 0	9 16 0	244	16 17 0	29 8 0
13	661	19 16 6	497	8 2 6	10 12 4	265	16 17 0	31 17 0
14	712	21 7 0	534	8 15 0	11 8 8	285	16 17 0	34 6 0
15	762	22 17 6	572	9 7 6	12 5 0	306	16 17 0	36 15 0
16	813	24 8 0	611	10 0 0	13 1 4	326	16 17 0	39 4 0
17	864	25 18 6	648	10 12 6	13 17 8	347	16 17 0	41 13 0
18	915	27 9 0	687	11 5 0	14 14 0	367	16 17 0	44 2 0
19	965	28 19 6	725	11 17 6	15 10 4	388	16 17 0	46 11 0
20	1016	30 10 0	760	8 0 0	16 6 8	408	24 16 0	49 0 0
21	1067	32 0 6	801	8 8 0	17 3 0	429	24 16 0	51 9 0
22	1118	33 11 0	839	8 16 0	17 19 4	449	24 16 0	53 18 0
23	1169	35 1 6	878	9 4 0	18 15 8	470	24 16 0	56 7 0
24	1220	36 12 0	915	9 12 0	19 12 0	490	24 16 0	58 16 0
25	1270	38 2 6	953	10 0 0	20 8 4	511	24 16 0	61 5 0
26	1321	39 13 0	992	10 8 0	21 4 8	531	24 16 0	63 14 0
27	1372	41 3 6	1029	10 16 0	22 1 0	552	24 16 0	66 3 0
28	1423	42 14 0	1068	11 4 0	22 17 4	572	24 16 0	68 12 0
29	1474	44 4 6	1106	11 12 0	23 13 8	593	24 16 0	71 1 0
30	1524	45 15 0	1143	12 0 0	24 10 0	613	24 16 0	73 10 0
31	1575	47 5 6	1182	12 8 0	25 6 4	633	24 16 0	75 19 0
32	1626	48 16 0	1220	12 16 0	26 2 8	654	24 16 0	78 8 0
33	1677	50 6 6	1257	13 4 0	26 19 0	674	24 16 0	80 17 0
34	1728	51 17 0	1296	13 12 0	27 15 0	694	24 16 0	83 6 0
35	1778	53 7 6	1334	14 0 0	28 11 8	715	24 16 0	85 15 0
36	1829	54 18 0	1373	14 8 0	29 8 0	736	24 16 0	73 4 0
37	1880	56 8 6	1410	14 16 0	30 4 4	755	24 16 0	75 4 8
38	1931	57 19 0	1448	15 4 0	31 0 8	776	24 16 0	77 5 4
39	1982	59 9 6	1487	15 12 0	31 17 0	797	24 16 0	79 6 0
40	2032	61 0 0	1524	16 0 0	32 13 4	817	24 16 0	81 6 8
41	2083	62 10 6	1563	16 8 0	33 9 8	847	24 16 0	83 7 4
42	2134	64 1 0	1601	16 16 0	34 6 0	858	24 16 0	85 8 0
43	2184	65 10 6	1638	17 4 0	35 2 4	878	24 16 0	87 8 8
44	2235	67 2 0	1672	17 12 0	35 18 8	898	24 16 0	89 9 4
45	2286	68 12 6	1715	18 0 0	36 15 0	919	24 16 0	91 10 0
46	2337	70 2 0	1754	18 8 0	37 11 4	949	24 16 0	93 10 8
47	2388	71 13 6	1791	18 16 0	38 7 8	960	24 16 0	95 11 4
48	2438	73 4 0	1829	19 4 0	39 4 0	980	24 16 0	97 12 0
49	2489	74 14 6	1868	19 12 0	40 0 4	1000	24 16 0	99 12 8
50	2540	50 16 8	1270	20 0 0	40 16 8	1021	24 16 0	101 13 4

DEPOSITS BASED ON VALUE					DEPOSITS BASED ON VALUE				
Value.	Holland.		Belgium.		Value.	Holland.		Belgium.	
£	£ s. d.	fls.	£ s. d.	frs.	£	£ s. d.	fls.	£ s. d.	frs.
1	0 1 0	3/5	0 2 5	3	200	10 0 0	120	24 0 0	600
5	0 5 0	3	0 12 0	15	300	15 0 0	180	36 0 0	900
10	0 10 0	6	1 4 0	30	400	20 0 0	240	48 0 0	1200
20	1 0 0	12	2 8 0	60	500	25 0 0	300	60 0 0	1500
30	1 10 0	18	3 12 0	90	600	30 0 0	360	72 0 0	1800
40	2 0 0	24	4 16 0	120	700	35 0 0	420	84 0 0	2100
50	2 10 0	30	6 0 0	150	800	40 0 0	480	96 0 0	2400
60	3 0 0	36	7 4 0	180	900	45 0 0	540	108 0 0	2700
70	3 10 0	42	8 8 0	210	1000	50 0 0	600	120 0 0	3000
80	4 0 0	48	9 12 0	240	2000	100 0 0	1200	124 0 0	6000
90	4 10 0	54	10 16 0	270	3000	150 0 0	1800	360 0 0	9000
100	5 0 0	60	12 0 0	300					

Spain is not included in this list, as the duty is charged on a complicated basis and must be worked out separately in each case. It usually amounts to about £70 or more for a car of average size.

CONTINENTAL CUSTOMS FACILITIES

Members and Associates of the R.A.C. can obtain special Customs papers (generally known as triptyques) from the Touring Department for the entry of their cars into Austria, Finland, Germany, Holland, France, Italy, Switzerland, Belgium, Portugal, Spain, Roumania, Russia, Norway, and Sweden.

The amount covering the Customs duties is deposited with the Club, and a refund is obtainable from the Club after the car has left the country to which the papers refer, provided the regulations, which are quite simple, have been duly carried out.

Full instructions are issued with each set of forms.

It will be understood that this arrangement is of the greatest convenience, for not only does it avoid the necessity of carrying about large sums of money, but it enables all money transactions with the Customs officials to be avoided, as it is only necessary to get the Club papers properly stamped and signed when crossing the frontiers.

INTERNATIONAL TRAVELLING PASSES

FROM THE "ROYAL AUTOMOBILE CLUB YEAR BOOK"

Explanation of the International Regulations.—Under an Order in Council the Club has been authorized by the Local Government Board to issue International Travelling Passes to motorists wishing to take their cars abroad, and the necessary arrangements have been made so that the Passes may be procured through authorized Examiners throughout the country. A number of Examiners have been appointed in the provinces, and in London applicants are examined by the Club Officials.

It is necessary for the car to be presented for examination in order to ascertain that it complies with the conditions laid down in the International Agreement, and, in addition, each driver must undergo a practical examination in driving to prove competency. Two photographs (head and shoulders) of each driver must be provided.

After this procedure has been complied with, the Club issues an International Travelling Pass; also a special oval plate bearing the letters "G.B.," denoting that the car comes from Great Britain or Ireland. This plaque must be affixed at the back of the car as near as possible to the ordinary British registration number.

The possession of the International Travelling Pass and Plaque allows the holder to travel in all countries which are parties to the Agreement, without obtaining special licences or carrying special numbers in each country as hitherto. This arrangement does not, however, in any way affect the Customs formalities.

The Passes hold good for a period of twelve months from the date of issue, and must be renewed annually.

Countries accepting the Pass, and Distinguishing Letters allotted to each:—

Germany	D.	Monaco	M.C.
Austria	A.	Holland	N.L.
Belgium	B.	Portugal	P.
Spain	E.	Russia	R.
France	F.	Roumania	R.M
Great Britain and Ireland	G.B.	Servia	S.B.
Greece	G.R.	Sweden	S.
Hungary	H.	Switzerland	C.H.
Italy	I.	Bulgaria	B.G.
Montenegro	M.N.		

DASHBOARD PLATES

Under the new International Regulations all motorists abroad must carry a plate on their cars, attached to the dashboard, facing the driver, bearing particulars of horse-power, engine number, weight (in kilogrammes) and country of origin of the car. The plate is about the size of a visiting card. Arrangements have been made for the department to supply these plates at the following prices:—

Black lettering on ivorine	1s. 3d. each.
Black ,, ,, brass	2s. 0d. ,,
Black ,, ,, nickel	2s. 6d. ,,

Ivorine plates can be prepared at twenty-four hours' notice, and metal plates at two days' notice.

FRANCE

Transport.—All arrangements for the transport of cars by any of the services specified may be made through the department, from which detailed particulars of these or any other services may be obtained.

Bordeaux from London.—Steamers every Saturday from London, carrying many cars, especially during the winter. The arrangements are satisfactory. Passengers are carried on the same steamers. Transit, about 67 hours. Transport, £3 10s. to £6 17s. 6d., according to weight: 10 per cent discount to Members and Associates. Return steamers leave Bordeaux Saturday or Sunday.

Bordeaux from Glasgow.—J. & P. Hutchison, 31 Hope Street, Glasgow. Every ten days. Transit, four days or more. Transport, £5 or £6. No passengers carried.

Bordeaux from Liverpool.—James Moss & Co., 31 James Street, Liverpool. Every Friday from Bordeaux. Transport according to measurement and weight.

Boulogne from Folkestone.—Excellent arrangements for cars, which are carried on ordinary passenger steamers. Two services daily in both directions. Transit, 1½ hours. Transport, £4.

Boulogne from Goole.—Three sailings per week in both directions. Limited passenger accommodation. Transit, about 20 hours. Transport, 30s. to 45s. Satisfactory arrangements.

Boulogne from London.—From London on Tuesdays, Thursdays, and Saturdays. From Boulogne on Sundays, Tuesdays, and Thursdays. Limited passenger accommodation. Transit, about 10 hours. Transport, 30s. to 45s. Satisfactory arrangements.

Calais from Dover.—Cars carried on cargo boats nightly in both directions, Sundays excepted, and on passenger boats only by special arrangements. Not recommended, as the service from Folkestone is much better. Cost, £4.

Calais and Dunkirk from Leith—Geo. Gibson & Co., 64 Commercial Street, Leith, and 24 Vincent Street, Glasgow. Steamers every Monday or Tuesday from Leith for Calais, and Thursdays for Dunkirk. Transit, about 40 hours. Transport, £4 or £5. Limited passenger accommodation.

Cherbourg from Southampton.—Tuesday, Thursday, and Saturday nights. Cars carried on ordinary passenger steamers. Transit, seven hours. Transport, £2 7s. 6d. to £4. Satisfactory arrangements.

Dieppe from Newhaven.—Cars carried on passenger steamers. Morning and evening services in both directions. Transit, about four hours. Transport, £2 10s. to £4. Satisfactory arrangements.

Havre from Southampton.—Cars carried on passenger steamers nightly in both directions. Sundays excepted. Transit, seven hours. Transport, £2 7s. 6d. to £4. Arrangements satisfactory.

Marseilles from Liverpool.—About every ten days from Birkenhead. Transit, nine days. Transport, £10. Passengers travel on the same steamers. Arrangements very satisfactory.

Marseilles from London.—Weekly service of cargo steamers. Transit, nine days. Transport, about £14. No passengers carried.

General.—The majority of French roads are very good, being broad, well engineered and straight, but the surface during dry weather is very apt to become loose and flinty. Level crossings, which are often badly lighted at night, and thus constitute a danger, are more numerous in France than in the United Kingdom. It should be remembered that petrol is more expensive in the large towns than in the smaller towns, and particularly so in Paris. All cars entering Paris are stopped at the gates, the petrol in the tanks is measured, and octroi duty charged upon it.

CUSTOMS

Special Customs Facilities.—Members and Associates may obtain special Customs forms (generally known as "triptyques") for the entry of their cars into France.

The Customs papers hold good for twelve months from the date of entry, and they permit of several temporary exits and re-entrances without obtaining new sets of forms.

Basis of Customs Deposits.—

Motor vehicles weighing less than 10 cwt.	£2	0	8	per cwt.
,, ,, from 10 cwt. to 49 cwt.	1	10	6	,,
,, ,, more than 49 cwt.	1	0	4	,,

Important Notes.—It is a very common error to imagine that when the chassis of a car is of French manufacture it is only necessary to pay duty on the body if the latter is of foreign origin. In such cases the full ordinary duty must be paid on the complete car. It is conceivable that by lodging a special application with the Administrator of Customs in Paris, an exemption from paying duty on the chassis could be obtained, but it would most certainly not be worth the trouble for temporary importation.

In the absence of Club Customs papers, the money deposited at the port of entry is refunded in full at any port or frontier Customs House when the car is leaving the country.

Automobiles of French manufacture may be taken into France free of Customs duty, *provided* a certain document called the "Passavant" is produced. This paper is the receipt of the Customs, which may be obtained when the car is *first* brought out of France, and is valid for one year only from the date of issue, but it can be renewed provided an application is made *before* the date of expiration. If not obtained at the time when the car first leaves France it is not afterwards procurable.

When the "Passavant" is not obtainable, a document signed by the manufacturer, stating that the car is of French origin, will in theory admit the car free of Customs, but the officials generally make a great trouble about accepting such a certificate, and it cannot, therefore, be depended upon.

The Customs' Offices on the French frontier are open for business from 7 a.m. to midday, and from 2 p.m. to 7 p.m , from March until October; from 8 a.m. to midday and from 2 p.m. to 6 p.m. from September till April on week-days, but at other times and on Sundays and Fair-days special officials are in attendance to clear motorists' triptyques for temporary exits and entries, and on the main roads a special service is maintained at the Customs Offices enumerated below for clearing motorists' triptyques on their first entry and final exit. Petrol contained in the tank is usually admitted free when the car comes from a country granting similar facilities to French motorists, but petrol carried in cans or "bidons" must be paid for at the Customs House. Two spare tyres and spare parts attached to the car described on the triptyque are admitted free as part of the car.

List of Customs Offices at which the first entries and final exits of cars furnished with triptyques can be made on Sundays and fête days :—

Dunkerque . .	Ghyvelde-route, Steenvoorde.
Lille . .	Halluin, La Marlière, Le Touquet, Wattrelos-route, Toufflers, Baisieux-route.
Valenciennes . .	Blanmisseron - Quiévrechain, Le Coq, Maulde, Malplaquet, Bettignies, Jeumont-route, Hestrud, Cousolre (Ville), Walleres-Morenrieux, Chain.
Charleville . .	Gué d'Hossus, Givet (4 Cheminées), La Chapelle.
Nancy . . .	Mont-Saint-Martin, Longlaville, Jœuf, Sancy-le-Bas, Auboué, Doncourt, Mars-la-Tour, Arnaville, Champey, Létricourt, Moncel-route, Arracourt, Jogneg.
Épinal . . .	Houveau-Saales, Wisembach, Plainfaing, La Schlucht, Ventron, Bussang, La Chapelle-sous-Rougement, Foussemagne, Montreux-Château, Delle.
Besançon . .	Abbevillers, Villars-sous-Blamont, Le Villers, La Cheminée, Les Verrières, Fourgs, La Ferrière-sous-Jougne.
Lyon . . .	Pont de Bellegarde, Bellegarde-Viaduc, Pont-du-Moulin-des-Pierres, Forons, La Cure (Ex-les-Rousses).
Chambery . .	Bassy, Desingy, Frangy, Serzin, La Caille, Evires-route, Saint-Jean-de-Sixt, Flumet, Séez, Lanslebourg, La Vachette, Larche.
Nice . . .	Caravan (Pont-Saint-Louis), Breil, Fontan.
Perpignan . .	Perthus, Bourg, Madame, Fos.
Bayonne . .	Béhobie, Urdos.

RULE OF THE ROAD

The rule of the road throughout France is to keep to the right and overtake on the left.

LIGHTING REGULATIONS

Lamps must be lit not later than fifteen minutes after sunset.

A green light should be shown in front on the left. A special liquid is obtainable from the Touring Department for colouring the lens.

According to regulations which came into force 1st January, 1909, it is compulsory to carry an *efficient* tail light on the left-hand side, which *clearly* illuminates the back number-plates at night-time. Brackets and tail lamps for use on the left are now procurable without much difficulty in the United Kingdom, but otherwise the regulation fittings should, of course, be obtained from a motor dealer immediately after arrival in France.

SIRENS

The use of sirens is forbidden, the regulations stating that notice of approach must be given by means of a "bell or horn," and a judicial decision given during 1908 confirms this law.

INLAND REVENUE TAXATION IN FRANCE

Not to be confused with the Customs Duties, which are quite distinct.

All motor-cars in France are subject to inland taxation, but cars entering France with a triptyque or "consignation," if not remaining in the country for a longer period than four months, will not be liable to this special fee. Motor-cars sojourning in France for a period exceeding four consecutive months will be liable (in addition to the fixed charge of 50 francs per motor-car with two seats, and 90 francs per motor-car with more than two seats), to the following extra charge:—

1 to 12 h.p. . . .	5f. per h.p.	37 to 60 h.p. . .	12f. per h.p.
13 to 24 h.p. . . .	7f. per h.p.	61 h.p. and over .	13f. per h.p.
25 to 36 h.p. . . .	9f. per h.p.		

Example.—A 20 h.p. motor-car having been in France for over four months—say eight months:—

Four seats		Fixed charge .	90f.
1 to 12 h.p. at 5f. per h.p.	. 60f.	. . . . .	116f.
13 to 20 h.p. at 7f. per h.p.	. 56f.		
			206f.

206f. divided by 12 (months) multiplied by 8 (months) equals 137.24f.

This tax is collected from visitors who keep their cars in France for more than four months by the Customs officials at the port of departure.

TABLE OF DISTANCES FROM PARIS

The following table gives approximate distances from Paris to various continental towns. It has been compiled merely in order to give some idea of the length of time which should be allowed for reaching the towns specified. It does not imply that the routes suggested are the best to follow in all circumstances; all information in this connection may be obtained from the Touring Department of the Royal Automobile Club.

In order to economize space, cross references have been found necessary; thus Marseilles is shown as being 95 kms. = 59 miles S.E. of Avignon, and there are three routes given to the latter town, so it is only necessary to add the distance indicated from Avignon to Marseilles in order to arrive at the total distance from Paris to Marseilles by any of the three routes outlined to Avignon.

When the name of a town is printed in **block** type, it indicates that the town is dealt with separately in its alphabetical order in the list.

PARIS TO

	Approximate distance. Kms.		Miles.
AMIENS via Pontoise and Beauvais	145	...	90
ANGERS via Rambouillet, **Chartres**, Nogent-le-Rotrou, Le Mans, and La Flèche	297	...	185
ANNECY via **Dijon**, Lons-le-Saunier, and Nantua .	536	...	333
AVIGNON (1) via Tonnerre, **Dijon**, **Lyon**, and Valence	709	...	441
(2) via Auxerre, Autun, and Lyon .	680	...	423
(3) via Fontainebleau, Nevers, Roanne, St. Etienne, and Valence . .	674	...	419

PARIS TO

	Approximate distance. Kms.	Miles.
BELFORT via **Troyes, Chaumont, Vesoul,** and Lure	448	278
BERLIN (Germany) via Meaux, Château-Thierry, Epernay, Chalons-sur-Marne, Sainte-Menehould, **Verdun,** Luxembourg, Treves, Berncastel, Mayence, **Frankfort a/M,** Fulda, Gotha, Weimar, Naumberg, Leipzig, Wittenberg, and Potsdam	2000	1243
BIARRITZ via **Chartres, Tours,** Poitiers, Angouleme, Bergerac, Marmande, Mont-de-Marsan, and Bayonne	805	500
BLOIS, 54 kms = 33½ miles S.W. **Orleans.**		
BORDEAUX via route to **Angoulême,** and thence via Barbezieux	590	367
BOULOGNE-sur-MER via Pontoise, Beauvais, Abbéville, and Montreuil	247	154
BOURGES (1) via Fontainebleau, Montargis, and Gien	217	135
(2) via Etampes and **Orleans**	247	154
BREST via **Chartres,** Le Mans, Laval, Rennes, and Loudeac	580	360
BRUSSELS via Coulommiers, Epernay, Reims, Rethel, Rocroi, Dinant, Namur, and Wavre	484	301
BUDA-PEST (Hungary) via route to **Vienna,** thence via Presbourg and Raab	550	963
CAEN via Mantes, Evreux, and Lisieux	214	133
CANNES (1) via Melun, **Dijon, Macon, Lyon,** Valence, **Avignon,** Aix-en-Provence, Brignolles	939	584
(2) via Melun, Auxerre, Autun, **Macon, Lyon,** and as No. (1)	880	547
(3) via Melun, Nevers, Moulins, Roanne, St. Etienne, Valence, and as No. (1)	904	562
(4) via **Lyon; Grenoble,** Sisteron, Digne, Puget-Theniers, and **Nice**	940	584
CARCASSONNE via Melun, Fontainebleau, Moulins, **Clermont-Ferrand,** Aurillac, Rodez, Albi, and Castres	840	522
CARLSBAD (Bohemia) to Eger via route to **Marienbad**	040	646
CHAMBERY via **Dijon,** Lons-le-Saunier, and Nantua	575	357
CHARTRES via Rambouillet	88	55
CHAUMONT via **Troyes** and Bar-sur-Aube	221	137
CHERBOURG via **Caen,** Bayeux, and Valognes	336	209
CLERMONT-FERRAND via Fontainebleau, Cosne, Nevers, and Moulins	385	240
COBLENZ (Germany) via Coulommiers, Chalons, **Verdun,** Luxembourg, Treves, and Wittlich	510	317

PARIS TO

	Approximate distance. Kms.	Miles.
COLOGNE, 85 kms. = 53 miles N.W. **Coblenz.**		
CONTREXEVILLE, 95 kms. = 59 miles **N.E. Chaumont** (via Montigny and Lamarche).		
DIEPPE (1) direct via Pontoise	175	109
(2) via **Rouen**	186	116
DIJON via Melun and Tonnerre	300	186
DINARD, *see* **St. Malo**	383	238
FOIX, 80 kms. = 49¾ miles S.E. **Toulouse.**		
FRANKFORT a/M (Germany) via route to **Berlin**	572	356
GENEVA (Switzerland) via **Dijon**, Genlis, Dole, Poligny, Champagnole, Morez, Gex, and Ornex	490	304
GRENOBLE, 110 kms. = 68½ miles S.E. **Lyon.**		
HAVRE (le) via **Rouen**	208	129
LIMOGES via **Orleans**, Romorantin, and Chateauroux	395	245
LOURDES, 40 kms. = 25 miles S.E. **Pau.**		
LUCERNE (Switzerland) via Provins, Nogent-sur-Seine, **Troyes, Chaumont**, Langres, Gray, Besançon, Pontarlier, Neuchâtel, and Berne	640	398
LYON (1) via **Dijon**, Beaune, and **Macon**	485	302
(2) via Melun, Sens, Auxerre, Avallon, Autun, and **Macon**	455	283
MACON (1) 121 kms. = 75 miles S. **Dijon.**		
(2) via Melun, Sens, Auxerre, Avallon, and Autun	390	242
MADRID (Spain) via route to **Biarritz** and thence via St. Jean-de-Luz, Behobie, Irun, St. Sebastian, Vittoria, Burgos, Lerma, Aranda, El-Molar, and Fuencarral	1342	834
MARIENBAD (Austria) via Coulommiers, Chalons, **Verdun**, Metz, Birkenfeld, Mayence, **Frankfort a/M**, Wurzburg, Ansbach, Nuremberg, Sulzbach and Eger	1022	635
MARSEILLES, 95 kms. = 59 miles S.E. **Avignon.**		
MENTONE, 62 kms. = 38½ miles N.E. **Cannes.**		
(2) via Grenoble, etc., as **Cannes** route (4) as far as **Nice**	942	586
MONACO, 20 kms. = 12½ miles E. **Nice.**		
MONTPELLIER via Melun, Fontainebleau, Cosne, Nevers, Moulins, Thiers, Le Puy, and Alais	750	466
MUNICH (Bavaria) via **Nancy**, Strassburg, Stuttgart Ulm, and Augsburg	840	522
NANCY via Coulommiers, Bar-le-Duc, and Toul	349	217
NANTES, 89 kms. = 55 miles S.W. **Angers.**		

PARIS TO

	Approximate distance. Kms.		Miles.
NAPLES (Italy) (1) via routes to **Cannes,** and thence via Genoa, Spezia, Massa, Grosseto, Civita - Vecchia, Rome, Frosinone, and Capua, 992 kms. = 616 miles from **Cannes.**			
(2) via route to **Turin,** and thence via Alexandria, Piacenza, Parma, Bologna, Florence, Perugia, Terni, and **Rome** . . .	1987	...	1234
NARBONNE, via Melun, Fontainebleau, Moulins, **Clermont - Ferrand,** St. Flour, Marvejols, and Beziers	770	...	479
NICE, 30 kms. = 18⅝ miles N.E. **Cannes** by route (4), deduct above distance from total.			
NIMES, 44 kms. = 27⅓ miles S.W. **Avignon.**			
ORANGE, 27 kms. = 17 miles N. **Avignon.**			
ORLEANS via Etampes	137	...	85
PAU (1) via route to **Biarritz** to near Mont-de-Marsan	763	...	474
(2) via **Orleans,** Chateauroux, **Limoges, Perigueux,** Agen, Auch, and Tarbes . . .	800	...	497
PERPIGNAN, 68 kms. = 42¼ miles S. **Narbonne.**			
PERIGUEUX via **Orleans** and **Limoges** . . .	495	...	308
ROME (Italy), 231 kms. = 144 miles N.W. **Naples.**			
ROUEN via Mantes and Louviers	126	...	78
ST. MALO via **Chartres,** Alençon, Domfront, and Mortain	383	...	238
TOULON, 150 kms. = 93 miles S.E. **Avignon** (via Aix-en-Provence).			
TOULOUSE via **Orleans,** Chateauroux, **Limoges,** Cahors, and Montauban	700	..	435
TOURS via **Chartres** and Chateaudun .	233	...	145
TROYES via Provins and Nogent-sur-Seine	167	...	104
TURIN (Italy) (1) via routes to **Lyon** and thence via La-Tour-du-Pin, **Chambery,** Modane, Mont-Cenis Pass, and Susa, add 324 kms. = 201 miles to distances to **Lyon,** by Lyon routes (1) or (2).			
(2) via **Chambery** and thence as above	890	...	553
VENICE (Italy) via route to **Turin** and thence via Casale, Pavia, Cremona, Mantua, and Padua . .	1230	...	764
VERDUN via Coulommiers, Chalon-sur-Marne, and Ste. Menehould	301	...	187
VESOUL, via **Troyes, Chaumont,** and Langres .	378	...	235
VIENNA (Austria) via **Nancy,** Strassburg, Stuttgart, Ulm, Augsburg, **Munich,** Muhldorf, Lambach, and St. Polten	1239	...	770

GERMANY

TRANSPORT

Bremen from London.—The Argo Steamship Company run steamers from London on Tuesdays, Thursdays, and Saturdays. Transit, about 36 hours. Transport, £3 3s. to about £4 15s. Passengers are carried on the same steamers. The arrangements are satisfactory.

Hamburg from London, by G.S.N. Co., from London on Wednesdays, Fridays, and Sundays. Transit about 40 hours. Transport, about £5.

Hamburg from Southampton, by the R.M.S.P. Co. Transport from about £3 to £6.

Hamburg from Grimsby, by G.C. Railway steamers. Daily service, Sundays excepted. Cars are carried on the ordinary passenger steamers. Arrangements satisfactory. Transport, 50s. per ton.

All arrangements for any of these routes can be made through the Touring Department of the Club.

CUSTOMS

			£	s.	d.	
Motor-cycles,	weighing	1 cwt. or less	2	10	0	per cwt.
,,	,,	1 cwt. and not more than 2 cwt. .	1	17	6	,,
Motor-cars	,,	2 cwt. ,, ,, 5 cwt. .	1	15	9	,,
,,	,,	5 cwt. ,, ,, 9¾ cwt. .	1	0	0	,,
,,	,,	9¾ cwt. ,, ,, 19¾ cwt. .	0	12	6	,,
,,	,,	19¾ cwt. or over	0	8	0	,,

TAXATION

When entering Germany a tax must be paid to the Customs officials, which is non-returnable. The taxation is a perfectly distinct transaction from the Customs duty, although it is payable to the Customs officers. It is similar to our Inland Revenue tax, but a special scale is enforced in the case of visitors.

On payment of the tax the officials supply a small booklet, known as a "Steuerkarte," and it is most important to get this booklet stamped and signed at every entry and exit. Care should be taken to see that this is done even when the final exit takes place and the owner does not contemplate re-entering the country.

SCALE OF TAXATION

Motor-cycles:	For a stay not exceeding 30 days in any year .		3 marks.
Motor-cars:	Permit available	1 day	3 ,,
,,	,, ,,	5 days	8 ,,
,,	,, ,,	15 ,, ...	15 ,,
,,	,, ,,	30 ,, ...	25 ,,
,,	,, ,,	60 ,, ...	40 ,,
,,	,, ,,	90 ,, ...	40 ,,

The period covered by the tax need not run consecutively, and the car can be taken in and out of the country as often as desired, provided the total number of days spent in Germany does not exceed the total time limit covered by the tax. The days of entrance and exit are counted as complete days.

The days during which a car may be laid up for repairs in a German town will be deducted if satisfactory proof, such as a certificate from the firm by whom the repairs have been executed, can be produced.

IDENTIFICATION PLATES

When an International Travelling Pass cannot be produced special Identification Number Plates must be carried, and are supplied by the Customs officials to whom the tax is paid on the frontier. A charge is made as follows:—

Motor-cycles, plates	2 marks.
Motor-cars, in cases where permit for one day only is taken out	2 ,,
Any other period	5 ,,

These plates are not, of course, necessary for holders of International Passes, but in the absence of the Pass the ordinary British car licence and driving licence must bear endorsements by a German Consul.

GENERAL REGULATIONS

Different regulations are in force in the various States, but, speaking broadly, they may be summarized as follows:—

Every car must be fitted with two efficient brakes.

Two lamps must be carried, one on either side of the car.

The light from the lamps must be reflected forwards through plain glass.

One lamp and one brake suffice for motor-cycles.

The speed limit during darkness or in populous districts is fixed at 15 kiloms. (9¼ miles) per hour.

On clear country roads the speed may be increased, and the driver is only liable to prosecution on the ground of driving to the public danger.

The rule of the road is to keep to the right and pass on the left.

There is no difficulty in obtaining petrol throughout Germany.

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[*Italic figures refer to plates facing such pages.*]

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